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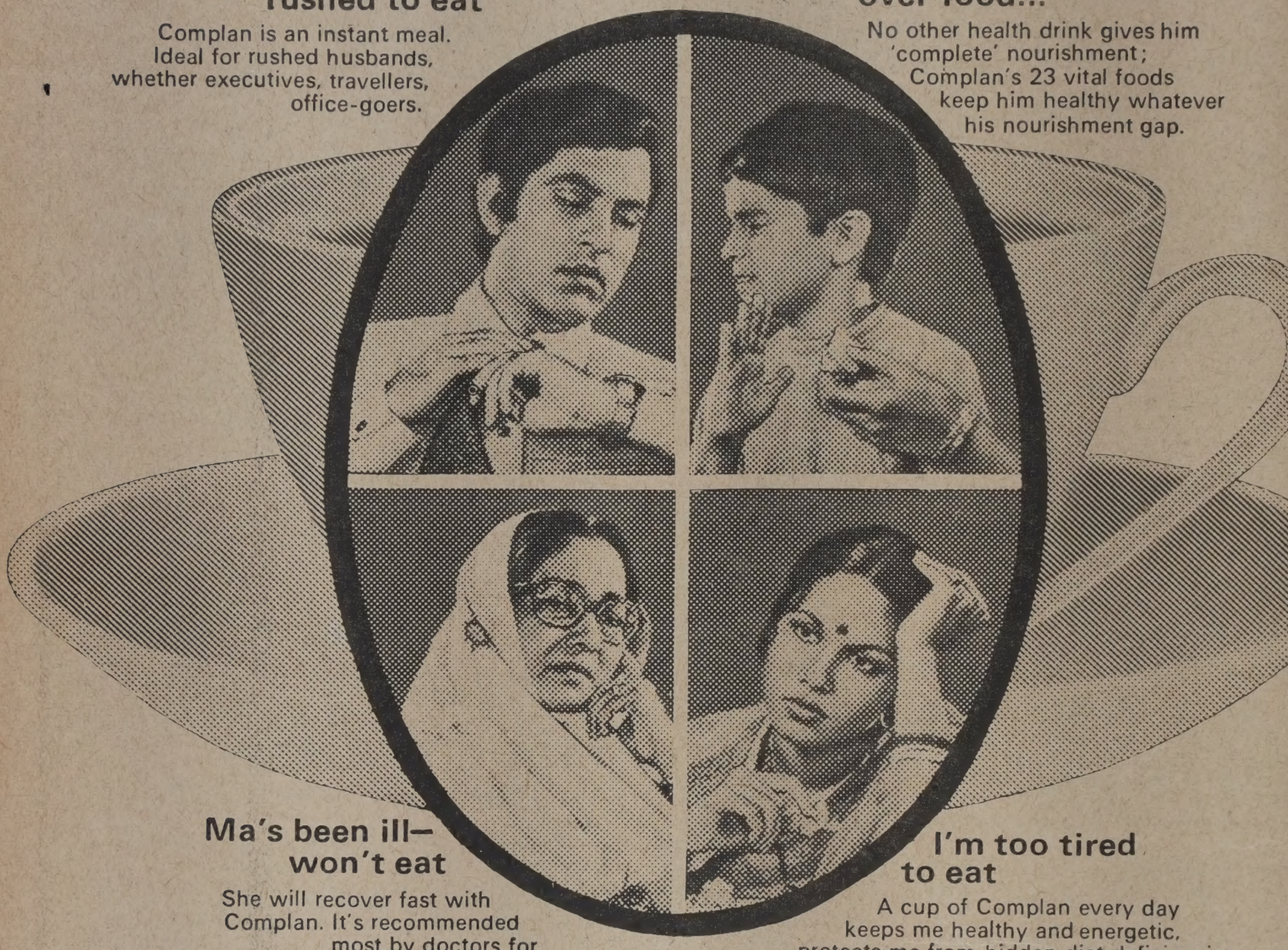

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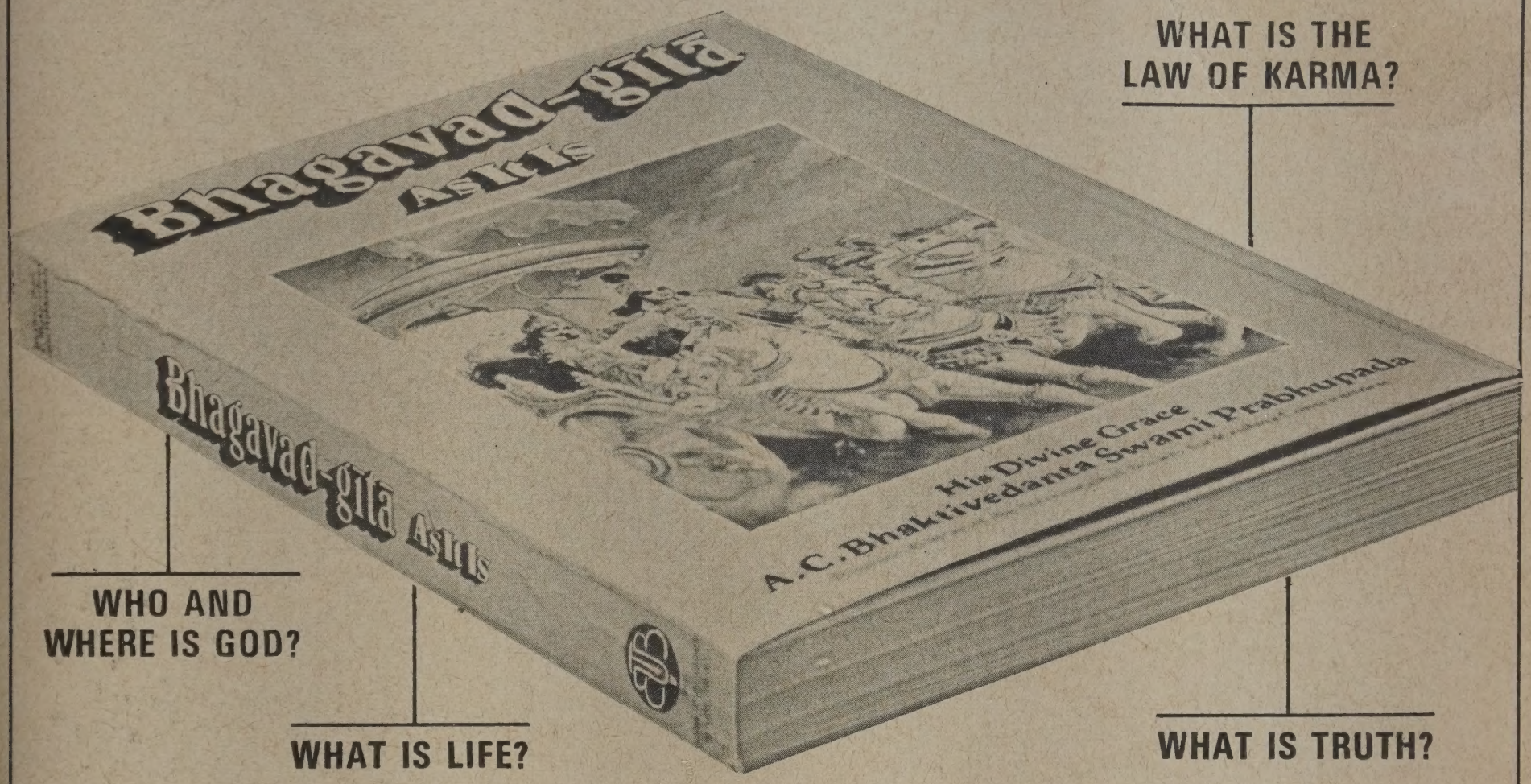

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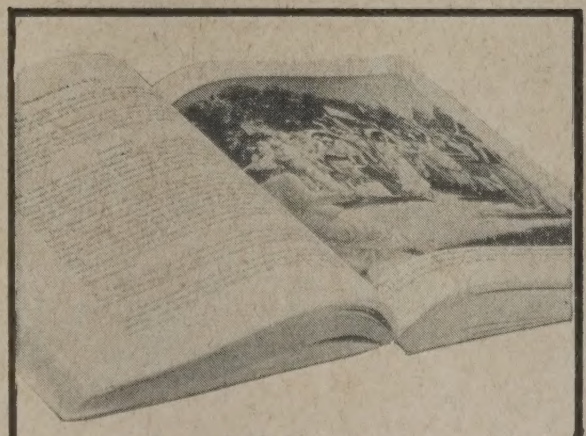

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COVER

Nana Shivalkar

[Clay model by Padekar Photographed by S. N. Kulkarni]

(Drawing of " The two hemispheres of the human brain " adapted from Vesalius's 7th century anatomical drawing)

EDITOR

SURENDR JHA

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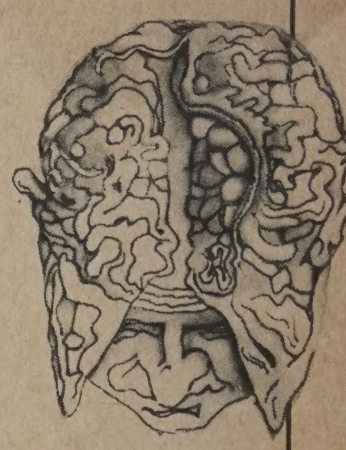
15–45 Memory



Can memory be improved as the mail order houses keep promising through the ads? The search for an answer prompted this special group of articles that try to probe the mechanisms of memory — at the biological, behavioural as well as cognitive levels

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In the case of electrical motor-driven gadgets, it's the repair bills that confound the user most. Half the reason may be design fault; the other half, our ignorance about their working. Concluding article in the three-part series

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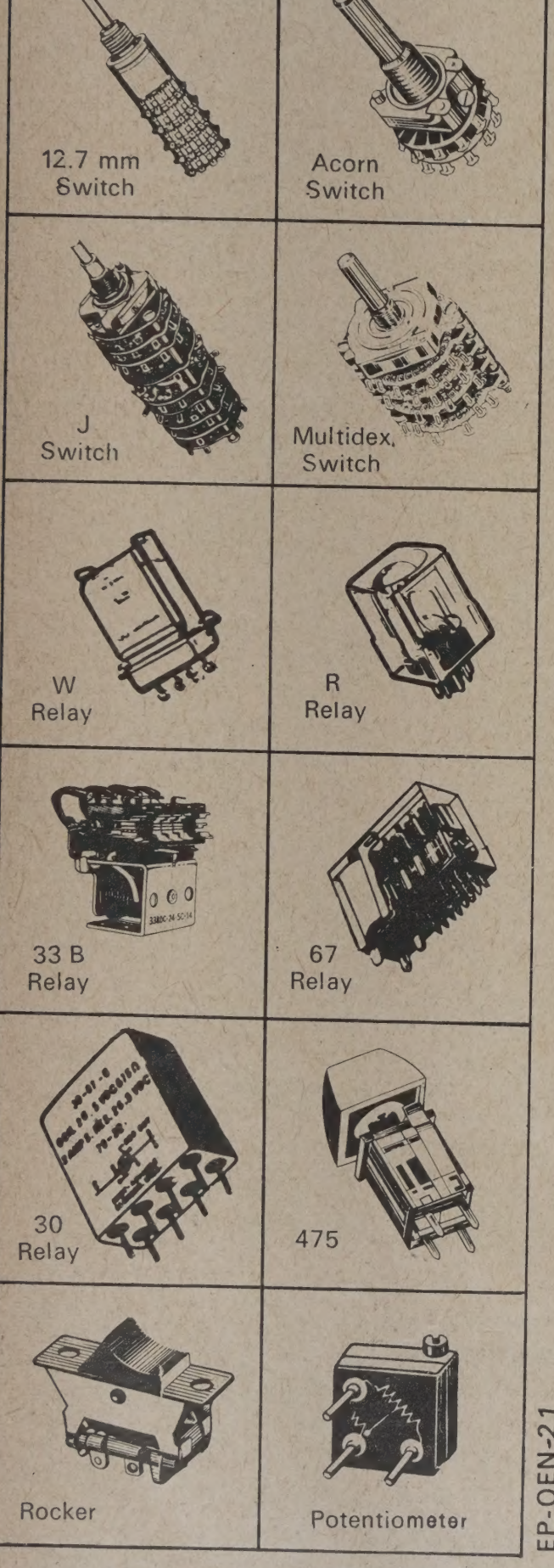

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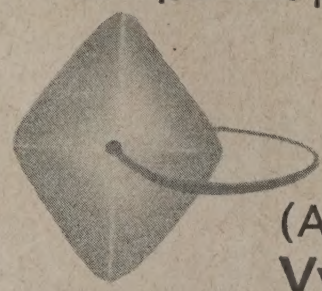

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Academic science and technological culture

In "Academic Science and Technological Culture" (August 1977), Prof. Narasimhan has voiced concern about the continued absence of what he has described as "work ethic" and "middlemen" and has pointed out the urgency of "bridge-building", between academic science and technology. It may be worthwhile to find out if similar catalysts were responsible for the construction of temples, advanced metallurgy as evident in the Iron Pillar near the Qutab Minar in Delhi, sea-faring vessels, etc in India and, if so, how such catalysts vanished.

To effect a speedy bridge-building, may I suggest that: (1) every science student should spend half his college tenure in a technological environment and this must be given proper weightage, unlike today's half-hearted practice; (2) the fabricator must invite the academician to spend time in his factory/field/mine and to obtain first-hand information and suggest means of improvement; (3) policy-making bodies in the country should include fabricators with proven ability in their respective fields, and such bodies should not be decorative but must have authority; (4) key men from the private sector must be invited to attend deliberations of the public sector industries; (5) the academician must make a conscious effort to instil a sense of dignity of manual labour in his students; and (6) fabricators should be induced to "adapt" one or more academic institutions in their branch of technology.

KALYAN K. GHOSE
Computer Maintenance Corporation
115, Sarojini Devi Road
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The gap between the "thinker-scientist" and "artisan-technocrat" in our society is too wide. For the "educated" class, "work-ethics" is a sneering term. The dominance of the western imperialist culture for over a century has created a western-educated elitist class of scientists, technocrats, engineers, doctors, etc; they have their elitist language, too. On the other side, we have the illiterate or semi-literate but "ingenious" class of artisans such as carpenters, blacksmiths, goldsmiths, masons and weavers — looked down upon as inferior, ignorant and useless by the elitist scientist-technocrats.

What we need is "middle-men" who can bring and interpret "science" to these rural artisans in their own terms and language; this needs the use of vernacular languages, not English. If this is done, the rural people would be quick to translate scientific ideas into their arts. Any culture, including a scientific culture, can grow only from the grassroot level.

M. G. TATIYA
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Prof. Narasimhan cites the "conscious" organisation of science by the so-called 'bridge-builders' through various institutions and philosophical clubs as one of the most important factors in the development of a technological culture — as if these bridge-builders were committed to doing this for the sake of scientific and technological advance. Invariably, all these bridge-builders either belonged to the ruling class or represented the class interests of the bourgeoisie. The organised scientific activity — the publication of books, lecture demonstrations, academies, philosophical clubs, etc — were financed effectively by private enterprise or by the State, which, in turn, represented the class interests of the capitalists. The creation of these institutions also represented the need of the new industrial bourgeoisie to take science into its own hands in order to make it serve their purpose of increasing profits. That is why they acted as a 'brake' whenever it came to scientifically examining, and possibly altering, the social system from which they drew their wealth.

If a technological culture is lacking in India today, it could similarly be traced to the existing modes of production — mostly feudal in the rural areas and capitalist in the large urban areas. So we find our science and technology lacking the necessary impetus the same way as medieval Europe felt it. On the contrary, the position enjoyed by science in China and the USSR brings out the dialectical connection between the stage of development of a society and the character of its science. One could infer that the solution lies not in creating more institutions to serve the interests of the bourgeoisie but in establishing new socialist relations of production.

V. RAGHUNATHAN
28/10, Rajinder Nagar
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Science policy — on the wrong track

The main reason for the slow progress of science in India and its poor impact ("New phase in science policy?" Letters, September 1977) on the rural people is the wrong policy of developing science programmes on western lines. And the problem is common in several developing countries. In our eagerness to catch up with the West, we have drawn up science and technology plans centred on the "urban man". The planners often blame "mass illiteracy" for the slow dissemination of scientific knowledge in rural areas. This is far from the reality. Was it not the uneducated villager of Punjab and Haryana who produced the "green revolution" in wheat? The villager will not lag behind in adopting what is best for him and his family. One often talks of modernising the tractor, but rarely thinks of improving the plough used by millions of farmers.

This is where rural people felt isolated from science. Too much sophistication confined to urban areas satisfying the needs of urban dwellers left the villager to think of science as a tool 'intelligently' used by 'affluent persons' to satisfy their material needs and boost their ego; he often looks on science with contempt.

What is needed is to correlate Gandhian principles with technology. The eminent economist Dr. E. F. Schumacher observed "... the great paradox of our age is that the Gandhian ideas were implemented not in India but in Red China, not there is no mass production, but production for the masses: there's enough for everybody's greed — all these ideas are Maoist but actually they come from Gandhi. They had their first enunciation in India and implementation in China — as far as I can see."

The CSIR took some initiative in adopting districts. But there is often a pitfall in such schemes. The villagers and scientists will see the problems quite differently, and the projects proposed by the scientists will not necessarily be meaningful to the villagers. And if projects are imposed on them, they are likely to be sceptical and may well resist rather than co-operate. Rural development schemes, in the broadest sense, require a good sociological approach and as much psychology as scientific knowledge.

A. JAGADEESH
Convenor
Society of Science for People
2-275, Nawabpet, Nellore 524 002
Andhra Pradesh

Is it mere platitude?

After reading the resolution of the Indian National Science Academy (September 1977), I felt pretty dejected. Though, by and large, it has pointed out the bureaucratic infiltration into the scientific community, it is not emphatic enough. There is no dearth of examples to expose the activities of the short-sighted and power-hungry bureaucrats and some of the egoistic higher echelons of the scientific community itself. But the most irritating are the politicians. It is they who should be held responsible for the slow growth of scientific progress in India. People who do not know the distinction between electron and neutron or between virus and bacteria make decisions on how many MW a power station should produce, or in which part of the country geological prospecting should be carried out.

Though, time and again, the glaring truth has been repeated ("... education which has no relevance to the needs of the country"), nothing has happened. Again, no attempt has been made to improve the social status of a "technical worker". All this has led to frustration and unemployment. Why can't a person work as an unskilled or skilled worker after his graduation? Why should a dull and reluctant student go to college only to master the art of dishonesty and lose some valuable years? It has been shown that university education of more than 70 per cent of the students has no bearing on the work they later do. Then why this fanfare about higher education? Surely, I have the choice to become a carpenter, but

hen my father would become a monk and
ny mother would shed endless tears and
ny friends would be scandalised in
eceiving me. That is the cultural milieu in
vhich we live.

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Dating old trees

D. P. Agrawal and Sheela Kusumgar
tate ("What is radiocarbon clock? Is it
ccurate"? Question & Answer, June
977) that it was assumed that the
ntensity of cosmic rays has not changed
vith time. How can we ascertain this?
f the assumption is wrong, radiocarbon
ating will also be incorrect. Further, the
roportional quantity of nitrogen and CO_2
n the past atmosphere of the Earth could
ave also changed the formation of ^{14}C
nd the assimilation of CO_2 by plants. If
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The authors first say that materials of
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arbon method and the dating starts after
he plant or animal 'dies'. Later, they
nention about dating old trees by this
nethod. The carbon dating method
elates only to the period after the 'death'
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Technical Services Division
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Dr. Agrawal writes: **If there were significant fluctuations in the cosmic ray flux in the past, they would be reflected in changes in $^{14}C/^{12}C$ ratios, and thus affect ^{14}C dates also. Earlier work on cosmic ray intensity in the last one million years has shown that there have been no significant fluctuations (Arnold, Honda & Lal in *Journal of Geophysical Research*, Vol. 66, 1961, p. 3,519). But to verify relatively short-term variations in historical times, studies have been made to compare ^{14}C-dated samples with well-dated historical and dendrochronologically-dated samples. The study reveals that there has been some variation in $^{14}C/^{12}C$ ratio in the past 5,000 years, though the exact magnitude has not been agreed upon so far.**

Trees add up a ring every year to their girth. When a new ring is formed, the older one becomes only a mechanical tissue and does not take part in the plant's metabolic activities; thus, for ^{14}C dating, it is a *dead* ring. But, as suggested by us, some plant nutrients may pass radially through these rings and add younger carbon to them (no metabolism is involved). Dendrochronology can be used only on cut trunks of trees and is, therefore, destructive.

I suggest these two books for further information—*Radiocarbon Dating* by W. F. Libby, Chicago, 1952, and *Radiocarbon: Calibration and Prehistory*, ed. T. Watkins, Edinburgh, 1975.

Sweetener for ice candy

This has reference to "A super sweetener" (Ideas & Inventions, August 1977). One of the problems faced by the Council of Scientific and Industrial Research-Polytechnology Clinics, set up to identify the problems of industries in different States and to refer them to R & D organisations within or outside the CSIR, is the development of an artificial sweetener to be used in the manufacture of ice candies. The product should be an acceptable, stabilised sweetener, conforming to the Food Adulteration Act, 1954. The ice candy should retain its shape for 24 to 28 hours when stored in a push cart with internal temperatures ranging between 20° and 25°C. The cost of production of the sweetener should not exceed Rs. 30 to Rs. 35 per kg. The demand for sweetener in Andhra Pradesh alone, where the study was done, is 150 kg/day.

I hope either the author, Dr. Malshe, or any of your readers will take up the problem.

G. VEERACHANDRA RAO
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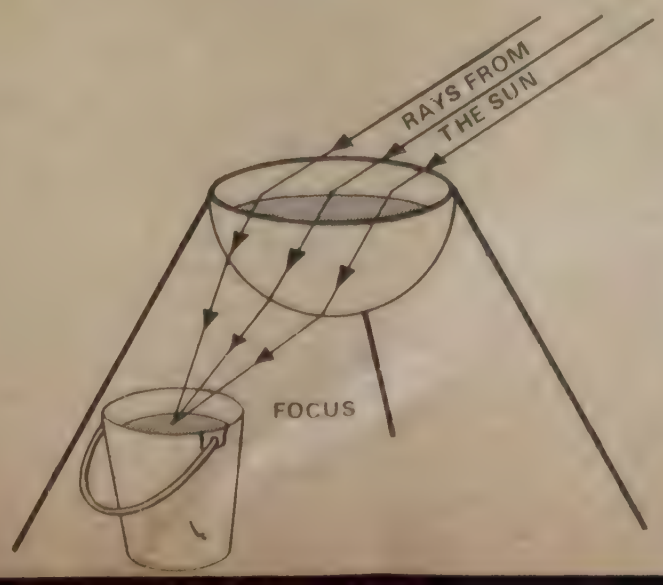
An alternative sun basket

Long before the "Sun basket" idea appeared in SCIENCE TODAY (Ideas & Inventions, May 1977), my science teacher had suggested to us a better and cheaper device based on the same principle. Cut out a polythene bag into a semi-spherical shape and join the edge to a circular metal ring of the same diameter. Fill this polythene basket to the brim with water and suspend it supported on stands. The focus of this half convex lens must lie about 30 cm above the ground at midday. The material to be heated is kept at the focus (see sketch).

This device costs less and its efficiency is higher than that of the sun basket. The disadvantages are that it would be less efficient when the Sun is not overhead, and that part of the water will evaporate. Also, the user must be careful not to burn his hand by placing it at the focus.



S. JAIN
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☐ **A similar idea was described in our July 1976 issue (p. 44)—Ed.**

The sal seed story

We refer to Mr. V. Venkappa's letter "Relevant technology" in August. Sal seed collection and sal oil production have been discussed in various seminars and forums and our Association wishes to make the following observations.

While it is correct that the labour is paid on an average Rs. 4 per day for the collection of sal kernels, it is not right to imply it is lower than normal. According to our information, it is in keeping with the wages paid to agricultural labourers in areas where sal seed is being collected. One should also note that a substantial part of seed collection is done by tribal women and children, who are unskilled and who do not necessarily find alternative employment. Hindustan Lever were the pioneers in locating a suitable forest contractor and in extending financial help to him to organise sal seed collection.

The contractors have to bear a number of other costs, like the cost of decorticating the seeds, packing in gunnies, transportation to railheads, payment of royalties to State Governments (the royalties vary from Rs. 100 to Rs. 500 per tonne), the cost of transit losses and loss of weight due to moisture evaporation. The price that solvent extraction plants can pay the forest contractors, in turn, depends on the cost of solvent extraction and the realisation on the sale of sal extractions and sal oil. The costs of seed collection and processing have a multiplier effect on the ultimate sal oil cost as the oil percentage is only 13 to 14. Sal oil prices depend, in the short term, only on demand and supply, and bear no relation to the cost of production. In the long term, of course, encouraging exports would mean higher prices to the contractors and higher wages to the Adivasis.

As far as we are aware, forest contractors do not make windfall profits. Nor do solvent extraction plants processing sal seeds earn significantly higher profits than those processing other oil seeds. Sal oil produced by the solvent extraction plants till recently found a market in soap production. Here again, several of our member firms have done pioneering work by further processing sal oil and exporting it.

Sal seed collection was first organised in a small way in 1967-68 when only about 2,000 tonnes were collected. It has now reached 1,50,000 tonnes. This implies that the tribals and Adivasis now get nearly Rs. 30 to 35 million in wages, where there was no such earnings before 1967-68.

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SUITING THE WORD TO THE DEED

With a lot of machinery and equipment being exported from one country to another, it is necessary that the manufacturers' instructions to the user be couched in as lucid a language as possible to avoid damage to the equipment or to the user. Most of us, for example, know how to operate a public telephone, but you would have to be a clever person if you could do it with a new model without any instructions whatsoever. This is all the more true in the case of complicated machinery. Even when the instructions are quite clear, it is generally helpful if simple affirmative sentences are used; introducing the passive or the negative either slows down the user or makes him commit errors.

Some years back, the pattern of public telephone booths in Britain was changed. In the new boxes, the instructions were worded negatively, for example, "Do not insert money until number answers". The Post Office has now thought it better to replace these with more affirmative instructions, so that the caller is told in correct sequence what he should do rather than what he should not.

It is unwise, says D. E. Broadbent of the Oxford University's Department of Experimental Psychology (UK), in an article published in "*Applied Ergonomics*" (March 1977), for instruction manual writers to write "before starting the engine, depress the carburettor plunger" instead of "after depressing the carburettor plunger, start the engine"; the latter sentence gives the correct sequence of operations.

Yet it may be quite suitable to use a negative when one has to challenge some presupposition of the reader and to use negatives or passives if they match more closely to the order in which the machine will be seen or unpacked.

CHOOSING THE SEX OF THE FOETUS

Since the genetic sex of an individual is determined by whether the egg cell is fertilised by an X-bearing sperm or a Y-bearing sperm, it might be possible to have a child of the desired sex by using sperms of the desired type — if a way could be found to separate the X-bearing and Y-bearing sperms. Several claims have been made in the past. In 1974, R. J. Ericsson and his team in Berlin claimed to have developed a method which utilised the differential motility of the sperms to separate them. Other workers, however, were not able to confirm the usefulness of the method. Now a team from the Institute for Research in Reproduction, Bombay, consisting of Padma R. Shastry, Umashashi C. Hegde and Shanta S. Rao, has in a letter to *Nature* (1 September 1977) reported a method of separating the two types of sperm cells without affecting their viability.

A suspension of spermatozoa from semen samples collected from volunteers was treated with a "density gradient" consisting of a mixture of Ficoll-400 and sodium metrizoate, and then centrifuged. After centrifugation, the sediment was rich in Y-bearing sperms, while the interface consisted mostly of X-sperms. The percentage of Y-bearing sperms was found to be 76·9 per cent, compared to 44·4 per cent before separation. The motility of and viability of the sperms was slightly reduced but this is attributed to centrifugation, and not to the density gradient.

TYPING WITHOUT THE TOUCH SYSTEM

Professional typists are taught to type blind, that is, without so much as taking a peek at the typewriter keys. Now the prototype of what may well turn out to be a new breed of typewriters makes it imperative on the part of the typist to 'see' what he types.

A post-graduate student at the University of Toronto's engineering department has developed a device which allows the typist to rattle off about 60 characters a a minute without actually touching the keys.

The principle behind it is fairly simple. A small screen which contains all the letters of the alphabet and some numerals, plus an optical tracking mechanism and control circuits, is mounted on an ordinary spectacle frame. When the eye rests on any character for one second, the digital controls instruct an electronic typewriter to pound out that particular character.

The device will be especially useful to those who have lost the use of their hands, to paralysed people or those suffering from diseases like cerebral palsy. The entire contraption is portable and can be set up in under a minute. It has been claimed that a commercial version, using standard components, can be produced for around $500 (Rs. 3,750 approx.) which is comparable to the price tags on some Indian typewriters in the market.

A TREE THAT NEARLY DIED OUT WITH THE DODO

The dodo, as every schoolboy knows, is dead and gone. But did its exit nearly kill something else too? Stanley A. Temple, an ecologist of the University of Wisconsin (USA), thinks it did (*Science*, 26 August 1977). He believes that the disappearance of the dodo at about the end of the 17th century from the Indian Ocean island of Mauritius has left the tree, *Calvaria major*, in the lurch. The tree, once common in Mauritius, is now down to about a dozen old surviving specimens.

Calvaria's stony fruits were an important source of food to the flightless bird. During its passage through the digestive tract of the dodo, the hard seed-coats were crushed by the stones in the dodo's gizzard, and in the course of evolution the seed wall became very thick to protect its embryo from damage when the dodo swallowed it. According to Temple, the seed wall has over the years become so thick that it does not allow the germinating embryo to emerge through it unless the seed wall has first been battered by an external agency such as the stones in the dodo's gizzard. Hence the decline of the tree.

However, calculations of the probable effects of a dodo's gizzard on the seeds showed that the hard seed coats would not have been totally demolished. Temple, who was undaunted by this piece of information, forced *Calvaria* seeds down the throats of turkeys. The gizzards of these birds are similar to a dodo's in that they, too, have gizzard stones for crushing food. Three of the seeds germinated. Temple says, these could have been the first *Calvaria* seeds to have sprouted since the dodo became extinct, some 300 years ago.

The dodo

BRAIN GAIN

The human brain has over the years gained weight. In a survey of brain weights from 1860 to 1940 it was found that the male human brain registered an increased average weight from 1,372 grammes to 1,424 grammes, while the female brain showed an increase in weight from 1,242 to 1,265 grammes.

Prof. J. A. N. Corsellis of the Department of Neuropathology at the Institute of Psychiatry in London and Dr. A. K. H. Miller of the Department of Neuropathology at Runwell hospital in Essex (UK), who together conducted the study, point out that between 1860 and 1900 the brain weight of women remained static. This 'dark age' is reflected in the lower overall rate of increase during this period in the brain weight of women. However, since 1900, women's brains showed an average annual increase of 0·62 grammes, which is only slightly less than the corresponding figure for males, 0·66 grammes a year.

Prof. Corsellis sums up his study as demonstrating a real increase in human brain weight. " Since weight and volume are known to be closely related, then (brain) size must also have gone up." But what the study failed to indicate — probably being outside its scope — was whether the increased weight has led to a corresponding increase in intelligence.

FLYING BICYCLE

Flying 40 metres under your muscle power seems to be more satisfying than flying 4,000 km in a supersonic transport. That seems to be the chief motivation of people who keep designing flying machines. The latest is Bryan Allen who last August pedalled his " Gossamer Condor " in California in a muscle-powered flight that lasted 7 minutes 28 seconds. The craft has a 21-metre propeller rotating at 96 to 108 rpm, which gives the craft a maximum speed of 19-20 kmph. The propeller is connected to bicycle-like pedals through a system of gears. The mylar-covered wing used piano wires for bracing and cardboard for its leading edge. According to Allen, with the addition of a 1·5 to 2 HP engine, the craft should be able to fly over the countryside on 27 litres of petrol.

CIGARETTES AND HEART DISEASE

The relationship between cigarette smoking and heart disease, especially arteriosclerosis (a hardening and thickening of arteries), has been based mostly on statistical evidence. Little was known about the physico-chemical mechanism. Now a clue has come from two Cornell University (USA) researchers, Carl. G. Baker and Theodore Dubin, who claim to have isolated a small protein, rutin, that may act as a catalyst in the scarring and occlusion of arteries. Rutin, they say (in a report in the *Journal of Experimental Medicine*), triggers the body's blood-clotting mechanism.

The researchers found rutin in both tobacco and cigarette smoke. How the blood-clotting triggered by rutin may affect artery walls and heart muscles is not precisely known, but the speculation is that, clotted blood can adhere to artery and heart walls and form a matrix for connective tissue cells to grow on, which might lead to a blockage of vascular passage ways.

ARTHROPOD CONQUEST OF THE LAND

In many ways, the arthropod invasion of the land some 400 million years ago, in the transition between the late Silurian and early Devonian periods, involved adaptations which remarkably anticipated those used by the lobe-finned fishes when they became the first land-living vertebrates. Like the latter, the first land arthropods evidently used modified swimming legs for walking on land and breathed air through modified gills.

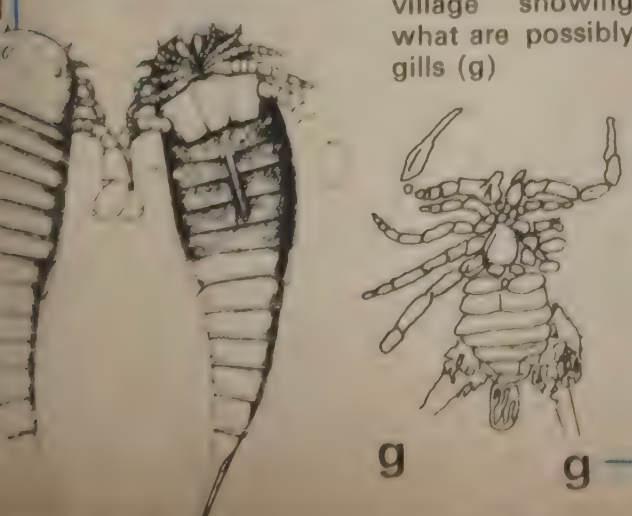
Two localities, Rhynie Chert in Scotland and Alken village in Germany, have yielded exceptionally well-preserved fossils of plants and arthropods which show in some detail their body structure and ecology, and how the transition from aquatic life to land life was made. Rhynie Chert was evidently a swamp and Alken a lagoon along the coast of an island. The more or less aquatic plants along the shores of the lagoon formed small 'mangroves.' This material and the wet plant debris on the beaches evidently constituted conditions very favourable for an invasion and gradual adaptation to life on land.

One of the species, a eurypterid (eurypterids are considered to be the ancestors of the modern scorpions) called *Parahughmilleria* was probably able to travel outside the lagoon, with the aid of its swimming legs. Air-breathing in these creatures might have been primarily possible because the gills were protected from drying by the plate-shaped abdominal appendages. At least some eurypterids might have had both gills and spongy masses called pseudotracheae (primitive respiratory structures found in certain arthropods). There are also fossil trails of eurypterids. Hence, most eurypterids were probably able to walk and stay on land to some extent. The pseudotracheae might be regarded as an adaptation that made possible survival during dry periods and during the desiccation of lagoons, estuaries and lakes. A similar adaptation is found in the fossil fishes which gave rise to the first land vertebrates.

The Alken fossils include a fossil scorpion, *Waeringscorpio hefteri*, which possibly had " book gills " instead of the " book lungs " of modern scorpions: hence it was probably aquatic, like most early scorpions.

The report on the fossils, by Leif Størmer of the Institute of Geology, Oslo (Norway), is published in the 30 September 1977 issue of *Science*.

(Left) Top (*a*) and bottom (*b*) views of *Parahughmilleria* showing swimming legs. (Right) A fossil scorpion from Alken village showing what are possibly gills (g)



PESTICIDE FROM PEPPER

Black pepper (*Piper nigrum* Linn.) long used by man as a condiment, may prove useful to protect stored food products from at least two pests.

Helen C. F. Su, in studies at the Stored Products Insects Research and Development Laboratory, USA, found that ground black pepper and its alcohol extract are highly toxic to both the rice weevil, *Sitophilus oryzae* (L.) and cowpea weevil, *Callosobruchus maculatus* (F.). Treatments with ground black pepper and the extract were generally toxic to rice weevils even at the lowest dosage of 625 pp/m on soft winter wheat.

When applied topically, the crude and purified black pepper extracts caused very high mortality. However, mortality was much lower among insects treated with piperine, the major component of black pepper, indicating a minor component may play the bigger role, according to Dr. Su, in an article in *Agricultural Research*, June 1977. Dr. Su believes that black pepper should be a safe source of naturally occurring insecticides.

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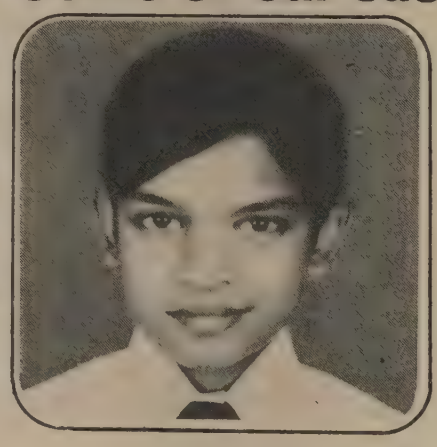

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HEADSTART

MEMORY

How would you describe it? Is it like a gramophone record that can be played again and again on demand? Or is it like photographs in an album, some clear, some fading with time? Is it something one person has more of than another? Can it be improved as most of us would want it to?

It was, to be honest, the last-mentioned aspect that was the germinal idea when this special issue on memory was planned. Some of our readers had written despairingly about how they had failed to benefit from rather expensive 'memory improvement courses'. Were they victims of fraud? After all, there are such things as mnemonic devices, some dating 2,000 years back to the Greeks.

In order to answer if memory can be improved, we have necessarily to begin with a number of other more basic questions: What is the mechanism of memory? If it is biological, which it must be since the brain is involved, where is it localised? What sort of modifications go on in the neural network that determine the nature and duration of retention? And how are these related to our cognitive behaviour? The three principal articles in this special section deal with these.

The first article is an exhaustive survey of much that has been investigated in the biological area. The second article looks into language behaviour in relation to memory. The third article looks at models of memory that psychologists have built in trying to answer questions on memory-related processes.

These three articles pose more questions than they answer. In the face of these gaping inadequacies in our knowledge about memory, it would be beyond our ken to attempt any technical evaluation of the so-called memory improvement techniques; all we have done in the concluding article is to describe some of these devices as they are used by mnemonists. The reader may be tempted to try them out. But with the reservation that, the 'memory' mnemonists talk about is not exactly all that biologists and psychologists have in mind.

The Biological Mechanism of Memory

OBAID SIDDIQI

Interest in human memory must be very old. The advantages of a good memory have been prized in all cultures that knew the value of learning. The teachers must have always enjoined upon their pupils "to remember and not to forget". Marcus Fabus Quintillian (AD 35–95), in a manual on the training of public speakers, prescribes three simple rules that govern the operations of memory:

First : attend closely

Second: practise

Third : if you hear anything new, associate it with what you know.

These, however, are practical matters. The philosophic beliefs of the ancient and medieval thinkers on the matter of memory are scattered and fragmentary. Plato had this to say: "I would have you imagine then that there exists in the mind of a man a block of wax, which is of different size in different men, harder, moister, and having more or less purity in one than in another.

"Let us say that this tablet is a gift of memory, the mother of the Muses; and that when we wish to remember anything which we have heard or thought in our own minds, we hold the wax to the perceptions and thoughts, and in that material receive the impression of them as from the seal of a ring; and that we remember and know what is imprinted as long as the image lasts; but when the image is effaced or cannot be taken, then we forget and do not know."

The idea that memory (*smriti*) is made of impressions (*samskara*) left by objects of perception on the mind recurs in the writings of several Indian philosophers. Patanjali lists memory as one of the five modes of mind, the other four being, right knowledge, wrong knowledge, fancy and sleep.

If memory was a block of soft wax in the mind, where was the mind? Although the Greek physician Galen

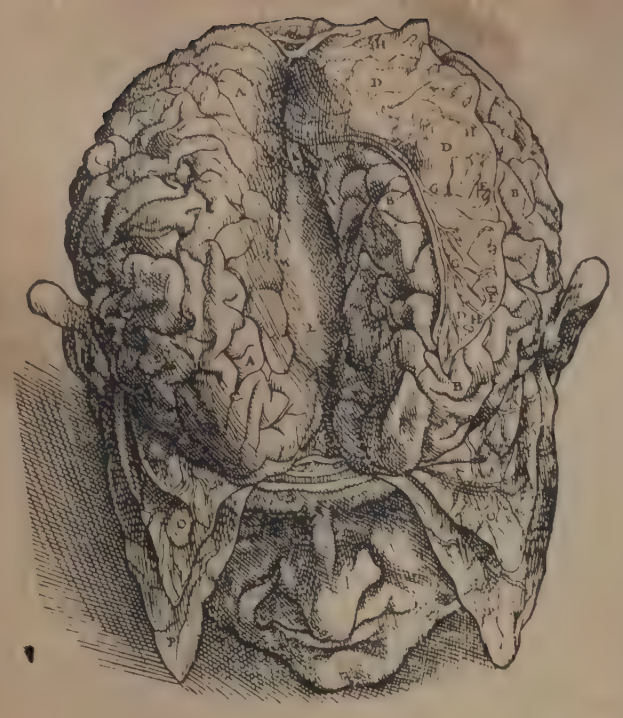


Fig. 1 The two hemispheres of the human brain depicted in a 7th century book on anatomy, *De Humani Corporis Fabrica*, by Vesalius

(AD 130–200) had an idea that the mind might be in the head, Aristotle definitely had it in the heart and thought that the brain was merely a refrigeration device meant to keep the heart cool. Aristotle wrote a treatise *De Memoria et Reminiscentia* and his views on the subject seem to have prevailed until the 16th century. St. Augustine, the brilliant Christian scholar 700 years after Aristotle, thought much about memory. To him memory and time were closely connected and this led him to a deeply personal view of both:

"The past is memory, the future expectation, the present attention. Or more precisely, since the present is the only one which exists, it follows that the present contains within it the past as present memory and the future as present expectation."

Leaving high philosophy aside let us turn to the question, when did scientific investigations of memory first begin? Sir Francis Galton (1822–1911) was a cousin of Charles Darwin. The impressive list of his professional preoccupations included medicine, exploration, meteorology, anthropology and the science of heredity. He also had a more than casual interest in how people remember things, in particular their mental imagery. Galton circulated a letter to a large number of his friends and acquaintances among scientists and scholars asking them to write down, as fully and clearly as they could, recollections of their breakfast table that particular morning. A close study of this material led Galton to make some highly original observations which are set out in a book, *Inquiries into Human Faculty*, published in 1883. This is probably the earliest example of the use of introspective reporting in the study of memory.

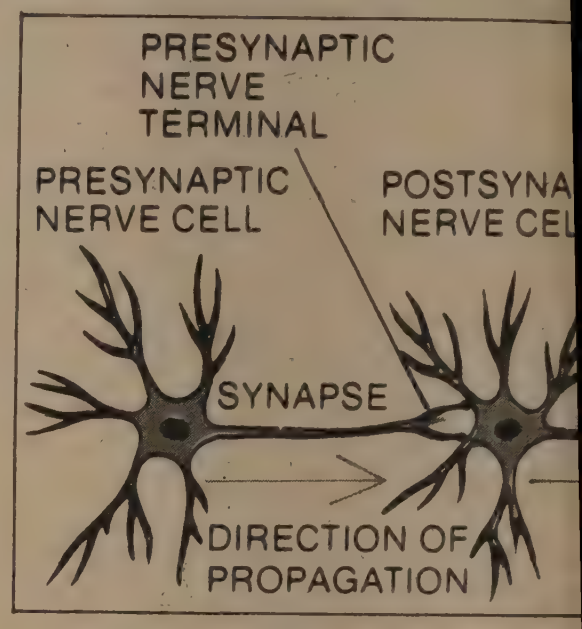
Hermann Ebbinghaus (1850–1909), German physician and psychologist, was a contemporary of Galton. He memorised random sequences of nonsense syllables and examined how long it took to learn such a sequence when forgotten with lapse of time. Ebbinghaus was the first to introduce a successful quantitative measure of retention, that is, time taken to relearn. All of Ebbinghaus's experiments were carried out with a single subject, himself. His results were published in a book, *Psychologie des Gedachtniss*, in 1885. The most impressive thing about these results is the fact that nearly every one of the conclusions reached by Ebbinghaus has stood the test of time and rigorous experimentation.

The researches of Galton and Ebbinghaus stimulated much interest in a quantitative study of learning and memory and mark the beginning of modern experimental psychology. Physical scientists are sometimes apt to turn their noses up at psychology and dismiss it as soft science. So far as our present-day knowledge of human memory goes, they could not be more in the wrong. Studying memory from without, experimental psychologists have found much about it that is interesting. [See the article by Dr. Ramani (pp. 34–40).] Psychological theories of memory are, however, of necessity phenomenological. When it comes to the anatomy and physiology of memory, we seem to know a great deal less. In this article I will try to tell you how much, or for that matter how little, we understand the biological mechanisms that subserve memory.

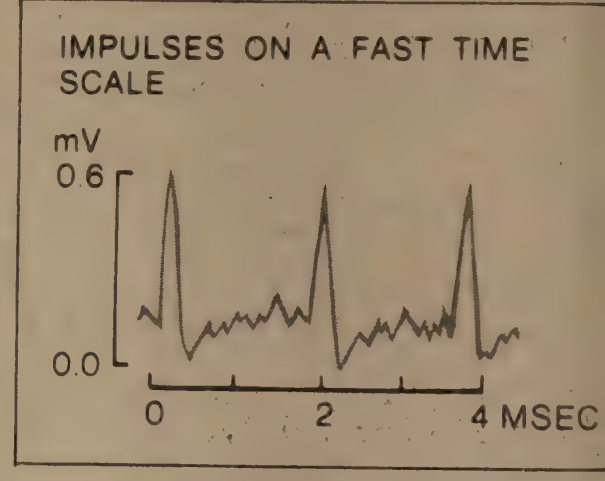
Memory is not an object or a "thing" like our little finger. It is an aspect of behaviour, something that we do. We read a poem or listen to a piece of music. Months, perhaps years later, in quite different circumstances, the lines of the verse or the notes of the melody come back to us. A dog is kicked by a policeman; the next time he sees this venerable guardian of the law approach, the poor beast slinks away. In either case, we infer that the past experience was remembered. Memory lies between learning and recalling. The study of memory is thus inseparably connected with these two other activities. One might think of memory itself as made up of three phases: an initial phase in which some experience or activity occurs in the brain, a final phase in which the activity of the brain is clearly influenced by the initial phase, and an intervening phase in which changes that happen in the initial phase persist through time.

Psychologists use the term *engram* or *memory trace* for the retaining phase, a somewhat inappropriate choice of words because it is likely to conjure, in the mind of the reader, the i of engravings upon a gramop record, somewhat like the Pla wax. We do not yet know much a the physiological basis of reta but there is no reason to doubt

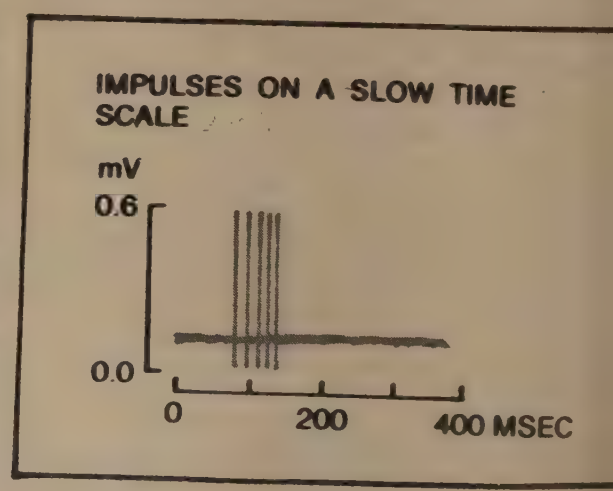
Fig. 2 NEURONS AND THEIR ACTI



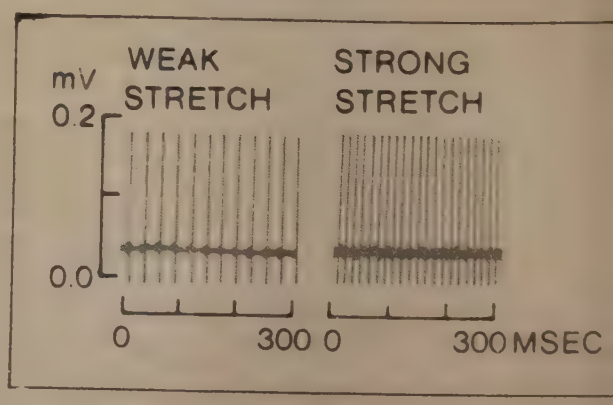
A. The axons of nerve cells make connect with dendrites of other neurons. N impulses travel along axons



B. The "all or none" impulse in a nerve fi is fixed in size. Different impulses are ind inguishable



C. On a slow time-scale, each nerve impul appears as a spike



D. The firing rate of nerve cells is propo tional to the stimulus they receive

taining is achieved by modifications the cells of the brain. What might ese modifications be? Where do they appen? What are the underlying olecular mechanisms? Whether or ot we can give satisfactory answers these questions now, the questions ouch upon matters which are nteresting in themselves.

In contemplating our own memoies we are acutely aware of the ividness of recollection. We recall ot just sequences of nonsense syllales, numerical arrays or geometric orms. We also recall with warmth, leasure, pain or anger. Memories, or us, are coloured with emotions. nevitably, therefore, we are led to ook upon memory as a reflection of our consciousness or self-awareness. Psychologists dealing with memory, not by introspection but with the help of experiments on people and animals, discovered very early that their observations could be analysed and understood just as well if they left "consciousness" completely out of their interpretations. This is not to assert that the admirable quality of self-awareness in our brains plays no part in our memories but simply to point out that so far as experiments go, the contribution of consciousness to the working of our memory has remained undetected. It must indeed be small and it is surprising how far we can go in thinking about memory from a purely mechanistic point of view.

Nerve cell and its activity

In order to talk about how the brain might *store memory*, we need to know something about nerve cells and their activity. Let us begin by taking a look at these cells. The nerve cells or neurons vary greatly in size and shape but all of them have a cell-body or trunk that gives out branches. The neuron has the appearance of a tree (Fig. 2A). Electrical signals travel along its cable-like branches. There are two type of branches. *Dendrites* are processes along which incoming electrical signals reach the cell-body. The signals generated in the cell-body travel outwards to other neurons along branches called *axons* or nerve fibres. The axons are the output cables of the nerve cell; these could be extremely long as, for instance, the axons of a sensory cell in the tail of a camel. A neuron can, therefore, be connected to other neurons far away.

At the end, the axon makes contact with the dendrites of the next neuron in the circuit. The junctions are called *synapses* (see Fig. 5A). At the synapse, the ending of the axon is in close association with the membrane of the receiving dendrite. We shall have more to say about synapses later.

Neurons connected to other neurons form neural circuits or networks. These circuits are not just randomly connected groups of cells. The human cerebellum, for example, has about 10,000,000,000 (ten billion) cells. These cells are of five distinct types, each occupying a particular region of the cerebellum and connected in a prescribed manner to other neuronal types (Fig. 3). One of the principal aims of neurobiologists is to discover the relationship between neuronal structure and function (at least they keep trying!). In some instances, they have met with success in this direction, as, for example, in understanding the processing of visual information by neurons of the eye and the visual cortex. There are strong reasons to suspect that the overall pattern of neuronal organisation and most of its connectivity (but perhaps not all) is controlled by the genes of the animal.

The nerve cells conduct their business by means of electrical signals. During the past two decades, we have come to understand a great deal about the biophysics of the signalling process. When a neuron is stimulated, it responds by undergoing a characteristic electrochemical disturbance in its membrane, causing a transient local change in electric potential across the membrane. The membrane potential rises rapidly by about a tenth of a volt and then goes back to its original state, the entire process taking no more than a millisecond or two (1 millisecond = one-thousandth of a second). The cell is said to have fired an action potential. The action potentials can be visualised by placing electrodes either close to the surface of the neuron or inside it and connecting these to sensitive amplifiers and voltage recording devices (Fig. 4). In a graphic record, the rapid change in voltage appears as a 'spike' which is the other commonly used name for action potential.

The action potential in one segment of the axon excites the neighbouring segment causing it to fire; this in turn excites the next neighbouring segment. The signal thus travels from segment to segment till it reaches the end of the axon. The nerve signals are not electric currents passively flowing along a conducting cable. What passes along the axon is an electrochemical disturbance that successively invades each segment of the axon; at each point the signal is regenerated anew and has the same amplitude and form. The action potential is, thus, a stereotyped 'all-or-none' event (Fig. 2B). A neuron can increase or decrease its firing rate in response to the stimulus it receives but each individual signal remains the same as

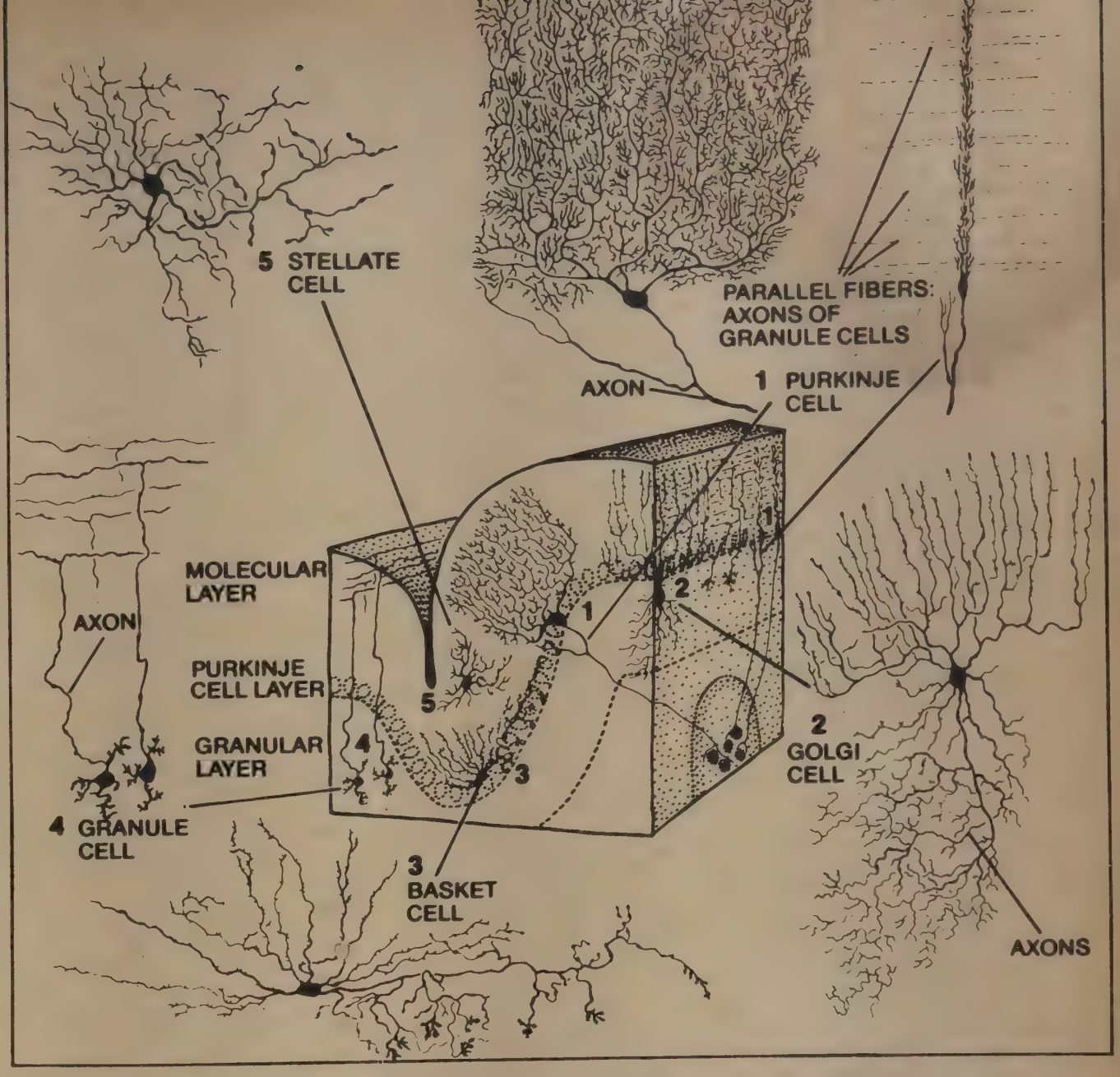


Fig. 3 The brain is an orderly structure. Billions of neurons in the cerebellum consist of five distinct types whose input-output connections are precisely defined. The central portion shows the three-dimensional arrangement of cells in a small part of the cerebellum

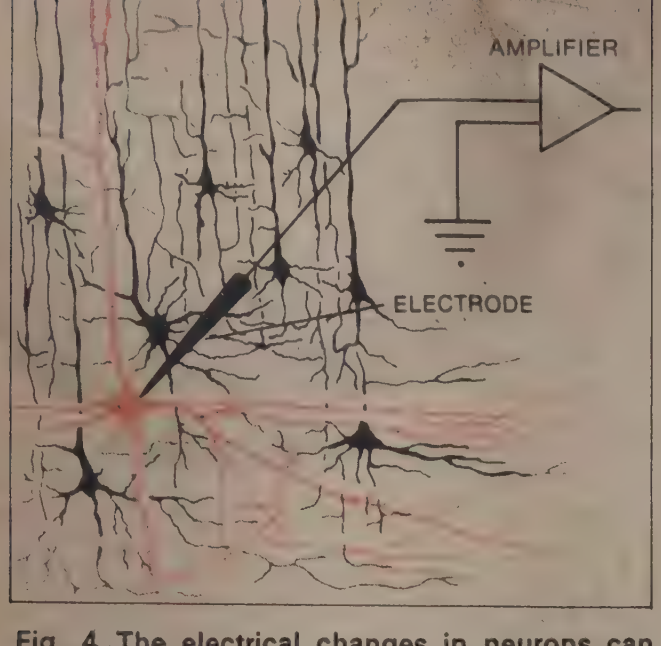
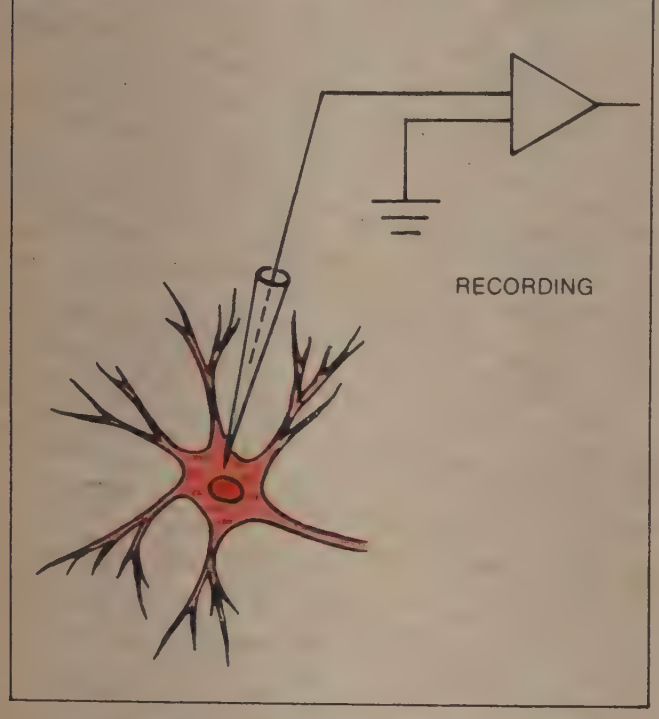


Fig. 4 The electrical changes in neurons can be observed by placing recording electrodes either inside the cell (above) or close to its surface (below)



every other signal. As the action potentials are distributed randomly over time, the signalling patterns of individual neurons, whose firing frequencies lie in a given range, are largely indistinguishable. As Sherrington clearly saw 50 years ago, the signals carried by a particular neuron derive their significance not from the pattern of signalling but from the connections the neuron makes with other neurons. The only possible exceptions to this rule might be neurons that generate periodic or phasic signals. The fact that most neurons fire in, more or less, the same way is an important point sometimes neglected by theories of memory that postulate translation of electrical signals into chemical structures. [See the section " Biochemistry of Memory ", p. 26.]

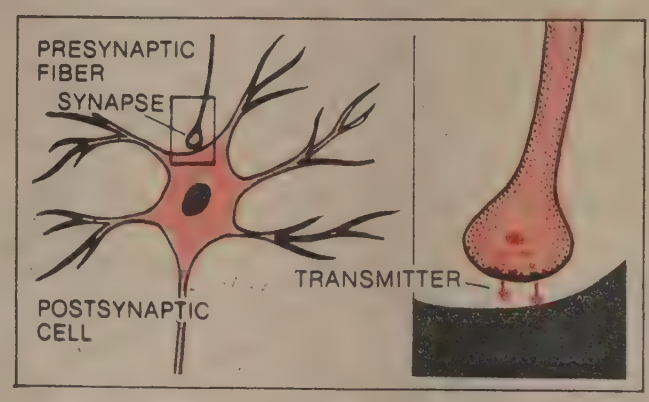
When the action potential reaches the end of an axon it encounters the synapse. The presynaptic part of the junction is a highly specialised structure packed with a chemical substance called the neurotransmitter (Fig. 5). Nerve signals at the end of the axon change its electrical potential and as the tip of the axon is depolarised, it releases the chemical transmitter in measured amounts proportional to the frequency of firing. The transmitter acts on the post-synaptic membrane and causes a potential change in the signal-receiving neuron. There are different types of synaptic junctions, each employing a characteristic transmitter. Some synapses are called electrical because the membranes of the two cells are electrically coupled and the depolarisation in the presynaptic ending spreads across the junction without the mediation of chemical transmitters. Synapses, both chemical and electrical, mark the ending of all-or-none transmission of signals. At this point the firing frequency is converted into an electric potential, passively spreading into the post-synaptic cell. This brings us to the second type of electrical signals with which neurons deal; although less well understood at present, these are far more important for our purposes than the all-or-none action potentials.

The synaptic potentials in the dendrites of the receiving neurons have three important properties. First, each synaptic signal has a characteristic sign; the potential may rise (depolarise) or fall (hyperpolarise). The synapses which cause depolarisation are excitatory (+), those which cause hyperpolarisation are inhibitory(—). Second, unlike the all-or-none firing in the axon the synaptic potentials are graded; the signal can have any value within a prescribed range depending upon the discharge in the presynaptic axon. Third, the synaptic potentials spread passively from the point of their origin, decaying in amplitude in a complex which depends upon the exact shape and material structure of neuron.

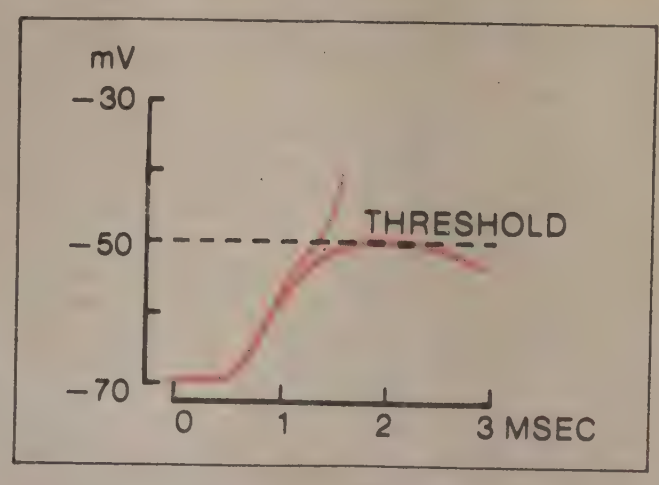
Imagine yourself sitting in a neu at the place where its axon origina This place, incidentally, is called a hillock. You are receiving syna signals from other cells thro hundreds, perhaps thousands, synapses, each contributing a cert amount of ' increase ' or ' decrea in potential. All that you note at hillock is the sum total of th changes. This is clearly not a sim sum. Some of the synapses contrib a great deal, either because they p duce large signals or because th might be situated close by. Oth may contribute little, because, instance, they might be located at far end of the thinnest dendrit When the summed potential at t axon hillock exceeds a certain thr hold, the axon will produce a burst spikes which will travel to the ne synapse.

What we have here is a ' summi amplifier ' which integrates the i coming signals according to a pr scribed set of rules. A neuron is n just an element of the neural circu It is a highly sophisticated devic capable of a great deal of informati processing. The output characteristi of this device are governed by forbiddingly complicated set of vari bles. *Any lasting change in these cha acteristics constitutes a potential mechanis of memory.*

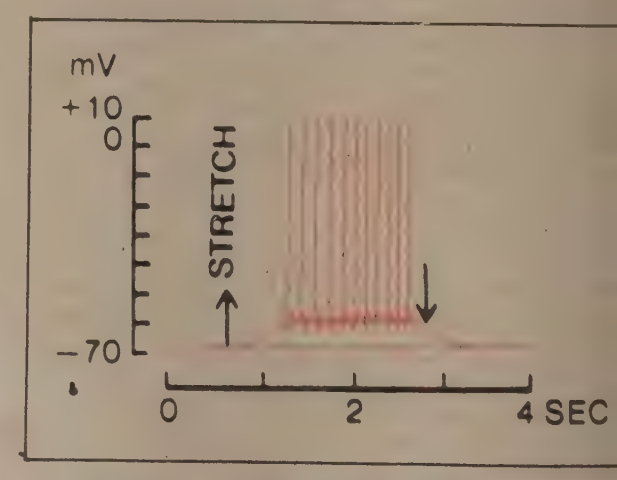
Fig. 5 ELECTRICAL SIGNALS AT SYNAPSES



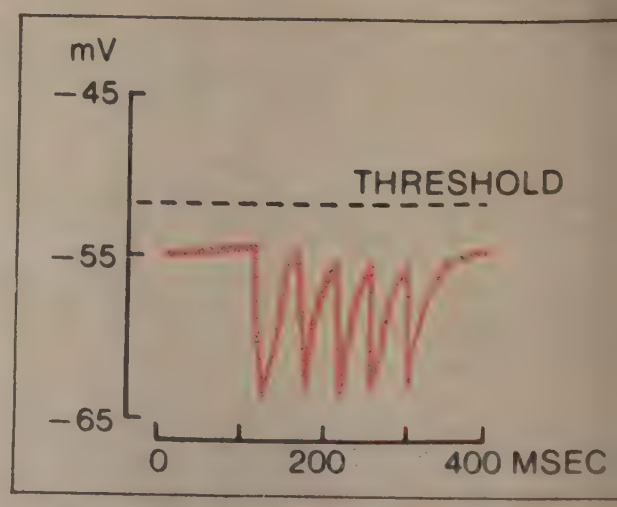
A. The junctions between neurons are called synapses. At most synapses, the presynaptic terminal liberates a chemical transmitter



B. At excitatory synapses, the transmitter acts on the post-synaptic cell to depolarise it towards its firing threshold



C. Adequate depolarisation leads to firing action potentials



D. At inhibitory synapses, the transmitter act to change the membrane potential away fro the threshold and inhibits firing

Very little is, at present, known
out the effect of experience upon
ironal parameters. Some theories
ribe learning to changes in synaptic
cacy; this might mean strengthen-
or weakening of existing synapses
formation of new ones. Likewise,
listribution of synapses on the dend-
ic surface, a change in the neuron
e or shape by growth and branch-
g, or chemical modifications of its
embrane could lead to the same
ult. The point to be emphasised is
at, although there are several emi-
ntly reasonable and realistic ways
which information processing char-
teristics of nerve cells could be
anged, we do not know how this is,
fact, done. This is not surprising
cause single neuron physiology is a
ld still in its infancy. Nearly all that
e know about synapses has been
arnt through experiments on frog
uscles or motor neurons in the spinal
ord of cats. No one has yet looked
the synaptic physiology of neurons
at might mediate learning and
emory.

hort-term memory

We can learn and
member in a matter of seconds.
lemory episodes of this order of
uration play an important part in
ur everyday life. It is a major finding
f experimental psychology that me-
ory can be of two distinct types:
ort-term memory and long-term
emory. The difference between these
vo types of memory may be seen
om the following experiment:

We train an animal, let us say, a rat,
perform some task. Our rat may, for
stance, be trained to avoid a parti-
ular turn in a maze. Sometime after
ne lesson is learnt, the animal is given
massive electric shock, in its head,
hich has the effect of confounding
ll ongoing electrical activity in the
rain. After the rat recovers from the
mewhat unpleasant effects of the
hock, its performance in the maze
an be tested again. We obtain the
llowing interesting result. If the
hock is given within five minutes of
he training, it completely prevents
earning. At 15 minutes, there is major
nterference with retention, while
fter one hour, the shock has practi-
ally no effect. The experiment shows
hat, for the first few minutes, memory
xists in a particularly labile form. It
an be completely disrupted by the
lectroconvulsive shock. Progressively,
nemory is converted into a more
table form, resistant to electric shock.
The conversion of short-term memory
nto long-term memory is called
consolidation'. Several treatments
uch as trauma (a hard knock on the

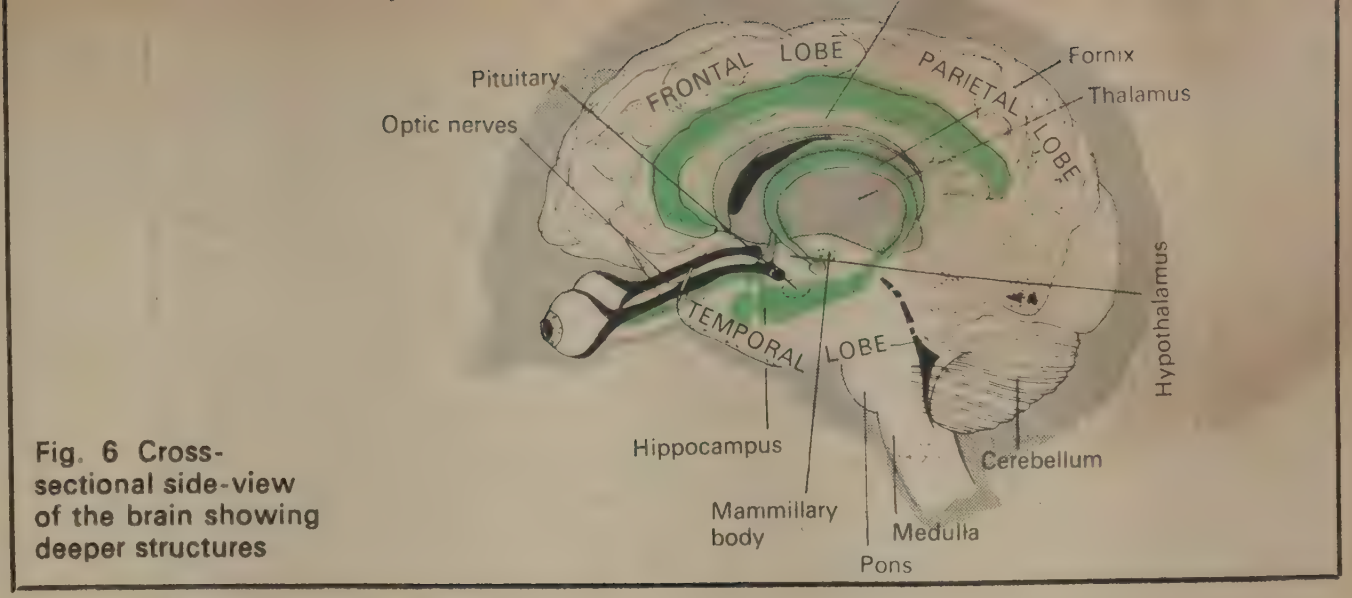


Fig. 6 Cross-sectional side-view of the brain showing deeper structures

head), low temperature and barbiturate anaesthesia have the same effect as electroconvulsive shock in preventing consolidation of short-term memory. The agents that produce *amnesia* (loss of memory) are known to affect the electrical activity of nerve cells. It is, therefore, likely that the mechanisms underlying the initial stages of memory are electrical. The brief period required for short-term memory to form is too brief to permit any appreciable chemical synthesis or growth in the nerve cell.

Fixation amnesia is a defect of short-term memory. Patients suffering from this disease are not able to retain experienced events for more than a short period. On the other hand, they can recollect, perfectly well, incidents in their lives before the onset of amnesia. The consolidation of short-term memory, in these patients, into stable forms appears to be blocked. The predicament of fixation amnesics is illustrated by the story of an old woman afflicted with this disability. The woman was taken to her village which she had not visited for over 20 years. Next day, when asked if she remembered her village, the woman replied, " Yes, almost as if I was there yesterday ". There is evidence that fixation amnesia is caused by destruction of nerve cells in parts of the brain called mamillary body and hippocampus (Fig. 6), which suggests that these regions are involved in the " stamping in " of memory.

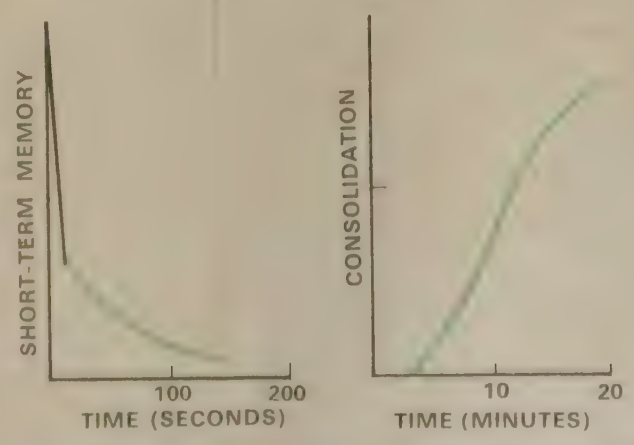


Fig. 7 Memory is made up of components which are distinguished by their respective modes of forgetting. (Left) Short-term memory consists of a very rapidly forgotten part (black) and intermediate memory (coloured). (Right) Gradually, short-term memory is converted to lasting memory traces

There is yet another kind of amnesia called *retrograde amnesia*. This is a temporary loss of memory which sometimes happens to people after brain concussion. On recovery, the amnesics regain their memory in a very peculiar manner. At first the oldest memories come back, followed by the more recent ones, strictly in the order in which they were formed until at last the events a few minutes before the accident are recalled. There is always a short period just before the accident which can never be remembered. This is the period of which the memory was never fixed. I had a brain concussion once. While playing Holi, I slipped and fell on a bucket which knocked me out for a couple of days. But that is what I was told by others. I have a perfect recollection of walking with the bucket in my hand but none whatever of the fall.

More refined experiments on the time-course of memory formation show that the short-term memory itself consists of distinct components. Far more information enters our brains through our senses than we can ever remember. There is a very rapid forgetting of most of this intake in less than a couple of seconds. A great deal of experience, thus, does not survive the instant of its passing and is irretrievably lost. The very first phase of memory probably exists as a pattern of neural firing in the brain for a brief period and then dies out as it is replaced by succeeding patterns of activity. If any of this experience is to last, it must be selectively preserved and re-established as a distinctive pattern of a somewhat longer duration. We might call this second stage, intermediate memory.

Following D. O. Hebb, physiologists often invoke reverberating circuits for short-term memory. The all-or-none action potentials circulating in neuronal pathways provide one conceivable mechanism for maintaining early memory. There is no direct experimental evidence that this is so. On the contrary, some of the evidence tends to support arguments against the idea that short-term memory

traces consist of nerve impulses continuously circulating in closed neuronal nets.

Some have suggested that the relevant electrical signs of short-term storage are to be found in slow potential changes arising from oscillations of synaptic potentials. Such oscillations show up as characteristic brain waves in EEG (electroencephalogram) records.

Lastly, electrical memory could be stored in special registers analogous to those used in electronic computers. However, there is no evidence to show that such registers exist.

Experimental conditioning and long-term memory

While it seems very likely that the mechanisms for storing labile short-term memory are electrical, this could hardly be the case for the stable memory which arises after consolidation. Electroconvulsive shocks, concussions or anaesthesia so deep as to cause electrical silence, leave long-term memory undisturbed. Stable memory, therefore, cannot be based on continuously circulating impulses or other electrical states of nerve cells; it requires a more enduring pattern of brain modifications. It is believed that long-term memory involves morphological or chemical alterations in nerve cells. The essential idea is that recurrent impingement of neurons by impulses or " synaptic bombardment " causes a durable change, making a particular neuronal circuit more susceptible to subsequent activation. Before we come to more explicit versions of this hypothesis, let us examine some of the experimental methods used to investigate memory consolidation.

Most experiments on consolidation make use of some form of training or conditioning. The best known among such experiments are those carried out by Ivan Petrovich Pavlov at the Medical Academy in St. Petersberg (now Leningrad) in the USSR. Pavlov began the studies which won him lasting fame and a second Nobel Prize after he had already received a Nobel Prize for his work on physiology of digestion in 1904. Pavlov's experiments were concerned with salivation in dogs. When a dog eats food, saliva flows in its mouth. This is an automatic reflex reaction that does not have to be learnt. A dog might also salivate when he sees a juicy morsel of food. This reaction is not an innate reflex and will not occur in a puppy. The dog learns to salivate somewhere along the line, watching its food before eating it. In the 19th century, people who considered this matter (in so far as they considered such matters at all) were likely to say that the dog had learnt that the visual image of food meant food, and salivation was a result of expectation. Pavlov wasn't so sure. He wasn't at all sure what words like ' learnt ' and ' expectation ' meant.

Pavlov's experiments were extremely simple. A bell was rung; at the same time a door opened and a tray of delicacies appeared before the dog. Naturally, the dog salivated. The far-reaching result was that after a few trials, the bell itself was enough to start salivation whether or not there was any food in sight. In Pavlovian terminology, the *conditioned stimulus* (the sound of the bell) had replaced the *unconditioned stimulus* (the food). This type of conditioning is called *classical conditioning*. Pavlov found that almost all stimuli, including usually painful ones, can be used to elicit salivation, if paired often enough with an unconditioned stimulus. The dog could be conditioned to salivate and wag its tail with pleasure in response to light, sound, touch, electric shocks or pin-pricks.

The importance of Pavlov's discoveries lies in the fact that *conditioned response learning is extremely widespread and appears to be a fundamental property of all neural organisation.* Pavlov recognised conditioning as a common ingredient of much of animal and human behaviour.

Classical conditioning is a simple form of learning. The experimenter contrives to associate an arbitrarily chosen stimulus with an innate, primitive response of the subject, usually a reflex activity such as salivation, knee-jerk, pupillary contraction and the like. There is a second form of conditioning called *operant* conditioning in which an irrelevant stimulus can be used to elicit a behaviour normally under the voluntary control of the animal. R. M. Yerkes found some 50 years ago that earthworms can be taught to turn right. A worm is placed at the base of a T-shaped tunnel. If, at the cross-bar, it right, the worm reaches a b succulent mud; if it turns left punished with electric shocks. the worm learns to turn right sistently. The element of rewa punishment is an essential ingre of operant conditioning. The t makes use of the natural *reperto* the animal's behaviour mouldi towards desired ends by a su system of reward and punishme carefully chosen combination of ant conditioning steps can lea startling accomplishments. By methods pigeons have been taug play table tennis, seals to blow b and bears to ride bicycles.

You might object that the chanical and automatic learnin worms and pigeons has little t with our own thoughtful learn Think of the worm at the cross-b the T-maze. When it makes the ri turn, the worm has some way t before enjoying the pleasures of cool mud. Some activity in its neu must make an *impression*, lasting enough to be reinforced by reward. The worm's education is so automatic after all. Consider matter a bit further. In a stand operant conditioning paradigm, a is taught to press a lever when a light goes on. This is simple to Occasionally, the rat will step on lever by accident. If the red l happens to be on, we might rew the animal by releasing a pellet food. He will very soon learn obtain food by pressing the le whenever the light goes on. If suc behaviour is exhibited by a child perhaps a chimpanzee, we are lik to say that he ' gets the idea ' and ' thinking '; in the case of a rat some lowlier animal we are apt imagine that what is involved mechanical and automatic. Expe ments indicate that the underlyi mechanisms in either case must similar.

Conditioning experiments show th

Photograph taken sometime in the first decade of this century shows Pavlov (centre) demonstrating his famous experiment on conditioning

ural mechanisms exist that will ablish new patterns of sensory-otor responses. The connections tween the triggering sensory input d the selected behavioural output e strengthened in preference to ner alternative motor programmes. is natural, therefore, to look for ssible neural changes that might company conditioning as the basis memory. Experimenters have been arching hard for such neural cor:e-es of conditioning in the hope of taining clues to the nature of arning and memory.

ectrical concomitants of arning and memory

The electrical activity nerve cells can itself be conditioned y appropriate pairing of stimuli. A w frequency stimulation of the ntral nucleus in the *thalamus* causes brief shift in surface potential ig. 8). If the electric stimulus is aired repeatedly with a sound tone, ter about 30 trials the thalamus lls respond to sound alone. Numer-us instances of such ' neuronal condi-oning ' are known. The fact that nsory or motor neurons can be onditioned by Pavlovian techniques ; by itself, neither surprising nor articularly informative. After all, if vert behaviour can be conditioned, ne must expect to find this reflected neuronal firing. On the other hand, study of conditioning and memory the level of neuronal activity raises ne hope that, by this method, one ight learn something about the rimary mechanism.

Of more direct relevance to the tablishment of memory are certain xperiments which claim to modify arning by electrophysiological inter-ention. Rabbits were trained to lift heir paws in response to flashes of ght. It was found that injection of egative charge in certain areas of the isual cortex blocked the retention of xperience acquired during electrical timulation. Injection of positive harge (anodal stimulation) in the ame areas had no effect.

Other electrophysiological experi-ents have been concerned with dentifying specific electrical con-omitants of learning and memory y analysing the non-specific electrical ignals called slow waves emanating rom different parts of the brain. It is elieved that the slow waves recorded rom a region are composite represen-ations of excitatory and inhibitory ost-synaptic potentials and other long-asting potential changes in the neu-ons of that region. Experimenters ave examined changes in the level f synchrony or intrinsic brain hythms during conditioning. Simi-

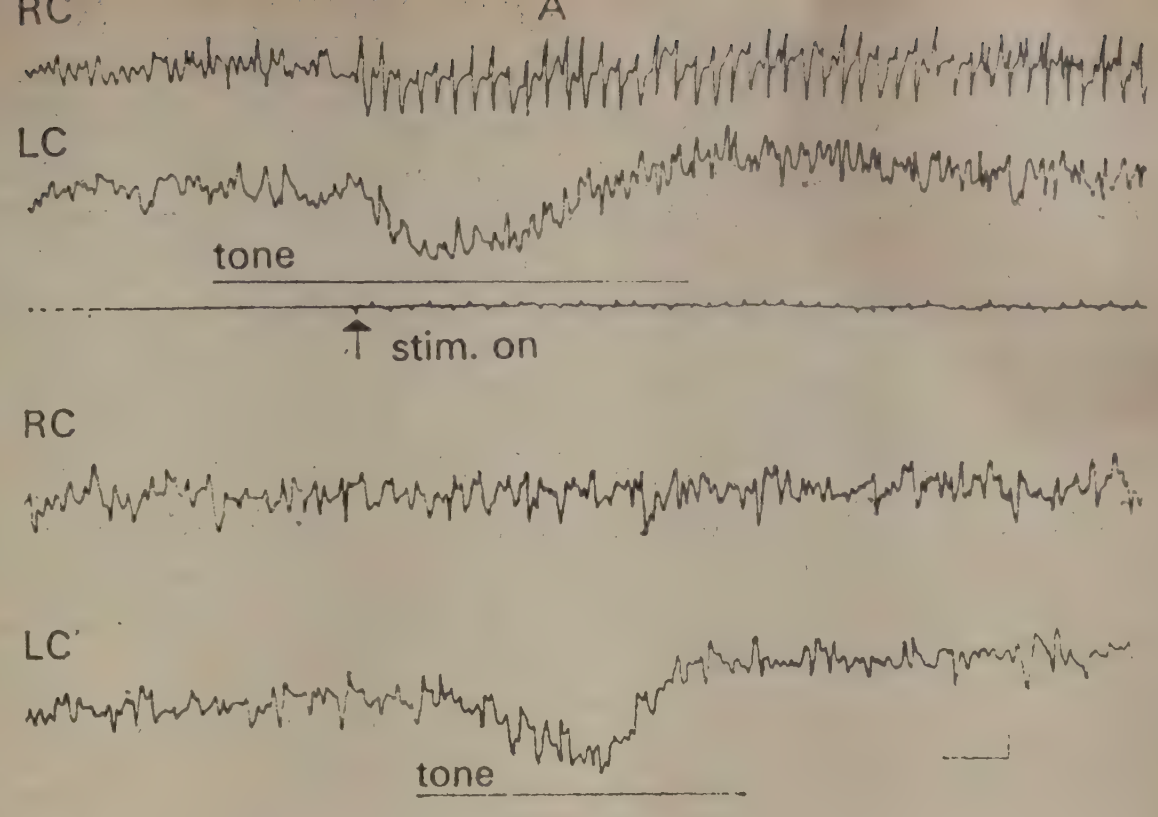


Fig. 8 Electrical conditioning of nerve cells. (1) Electrical stimulation of thalamus causes a slow potential change. When electrical stimulation is paired with sound tone repeatedly, the tone can by itself elicit the response. (2) Single light flash causes nerve cells to fire; repetitive flashes cause repetitive bursts. After several repetitive stimuli, a single flash may evoke a repetitive response

larly, characteristic changes in evoked potentials correlated with the establishment of conditioned responses have been observed. There is voluminous literature on this area and the subject tends to be somewhat technical. I will, therefore, restrict myself to just one example.

W. R. Adey at the University of California at Los Angeles found a special six cycles per second wave in the brain of a cat during maze learning. This wave spreads to various regions such as reticular formation, brainstem and visual cortex believed to be involved in the learning task. Every time the cat made a mistaken move in the maze, the phase relationships of the six-cycle wave in different regions underwent characteristic changes. Adey concluded that the *approach wave* must be an *electrical signature* of some brain mechanism which is the basis of learning and memory.

Studies on electrical correlates of learning have produced some interesting and intriguing observations, but so far, on the whole, do not throw much light on the mechanism of memory consolidation.

Formation of nerve connections

Let us now examine the possibility of new morphological connections between neurons as a mechanism of long-term memory. Although the overall organisation of the nervous system is quite securely specified by genes, the rigidity of these specifications varies within wide limits between different species. The stereotyped behavioural repertoire of certain insects appears to be wired into a fairly invariant pattern of nerve connections. As we move higher up in the scale, the situation changes. In mammals, too, a large part of the network must be strictly prewired; this would include parts of the old brain controlling vital functions or innate unlearnt responses. Areas such as the sensory-motor cortex or the cells of the visual cortex seem to be fairly closely

determined, although the experimental evidence here admits of some plasticity; regions of the cortex serving complex and elaborate functions may, on the other hand, possess much greater variability of connections.

Our views about the nature of associative connections have, in the past, tended to oscillate between two extremes. Some have looked upon the entire network as an initially undifferentiated " equipotential " system in which dynamic structures arise " by uniting distant points in a common task ". These structures are believed to be " complex, plastic and self-regulating ". The opposite view emphasises the prewired, " deterministic " character of the neural ensemble. Long-term memories are believed to depend upon changes in pre-existing synapses.

Brain cells do not divide, but they can grow new branches. In the first few years of life, the cortical cells in the brain of a child branch extensively (Fig. 9). Along with this profusion of neural connections goes the acquisition of new abilities, including learning ability. It is a reasonable guess that the two processes are connected.

If continued branching and interconnection of neurons is to serve the needs of memory, it must somehow be coupled to experience. Hubel and Wiesel were the first to study the effect of sensory deprivation on the nerve cells in the cortex of newly-born kittens. They found that the circuits that analyse visual input to the cortex are present at birth. Sensory deprivation for particular types of stimuli causes degeneration of neurons, leading to a selective loss of feature detectors. Others claim that the final wiring of 'analyser circuits' may itself be aided by visual experience. Be that as it may, these experiments point towards possible mechanisms that give rise to experience-dependent connectivity.

The brain contains large numbers of cells called glia. The glia form a matrix in which the neurons are embedded. It has been proposed that the glial cells can somehow guide the growing neural branches to form the right connections. Glia divide while neurons do not. The electrical activity in the neurons could conceivably stimulate the surrounding glia to multiply and, in turn, reinforce certain connections. All this is pure conjecture. As Sir Bernard Katz has said, the only thing common between glia and memory seems to be that we know little about either.

In short then, our knowledge of mechanisms that might regulate changes in neuronal connections is extremely inadequate. In particular, we know next to nothing about how experience might modulate these connections. Long-term retaining by the nervous system requires persistent changes in the brain. But, as yet, these changes are not accessible to methods of physiology and anatomy, and not much can be said with confidence about their nature.

Localisation of memory

If we do not know what memory traces are, can we say something about *where* they are? Nerve cells in precisely marked parts of the cerebral cortex control sensory and motor functions of the animal. As shown by the remarkable experiments of David Hubel and Torsten Wiesel on the visual cortex, the cortical cells that analyse characteristic features of the sensory input su shape, colour and movemen stacked in an orderly syste columns and rows. Are the cells ing with functions such as lea and memory also localised? above question has occupied the tion of neurologists for a long being connected with the larger tion of localisation of higher m functions.

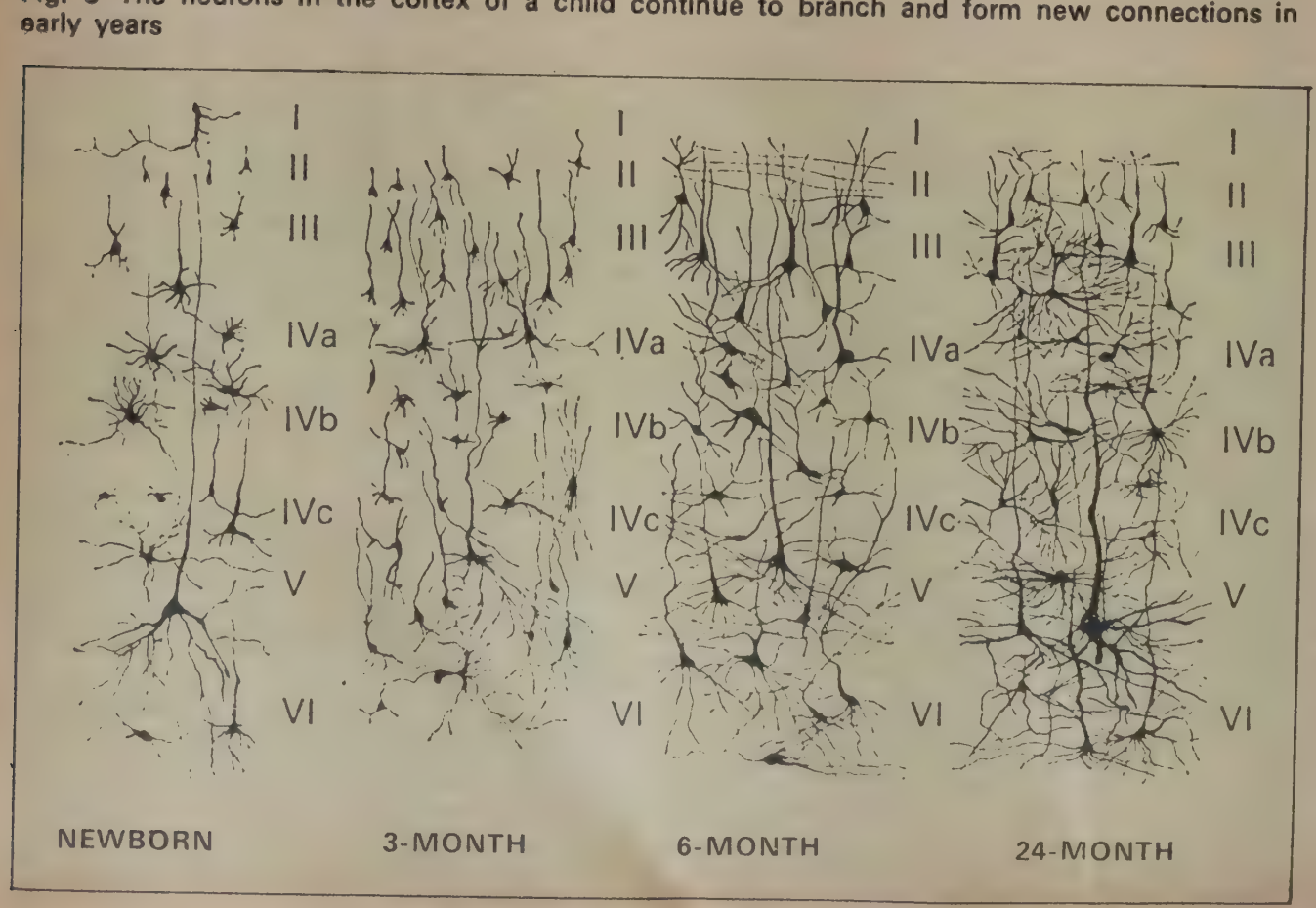
Franz Gall (1825) was a lea anatomist of his time who held each mental faculty was located definite part of the brain. Gall structed detailed phrenological in which domestic instincts, des tive inclinations, attraction to aptitude for education, love of par self-esteem and other such traits localised.

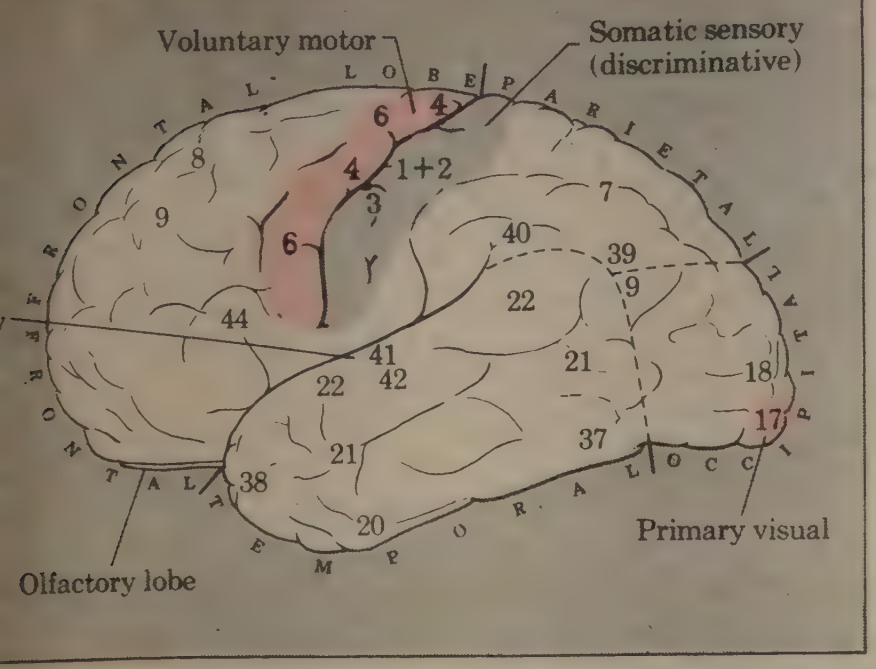
The opposite view was that t are no essential organs for me functions and there is no necessity them. In the words of Joseph L (1900), " The assumption of cer of association is just as erroneou the assumption of a centre of ordination in the heart. Associa is, like co-ordination, a dynam property determined by the ductivity of the protoplasm. Asso tive processes occur everywhere in hemispheres ".

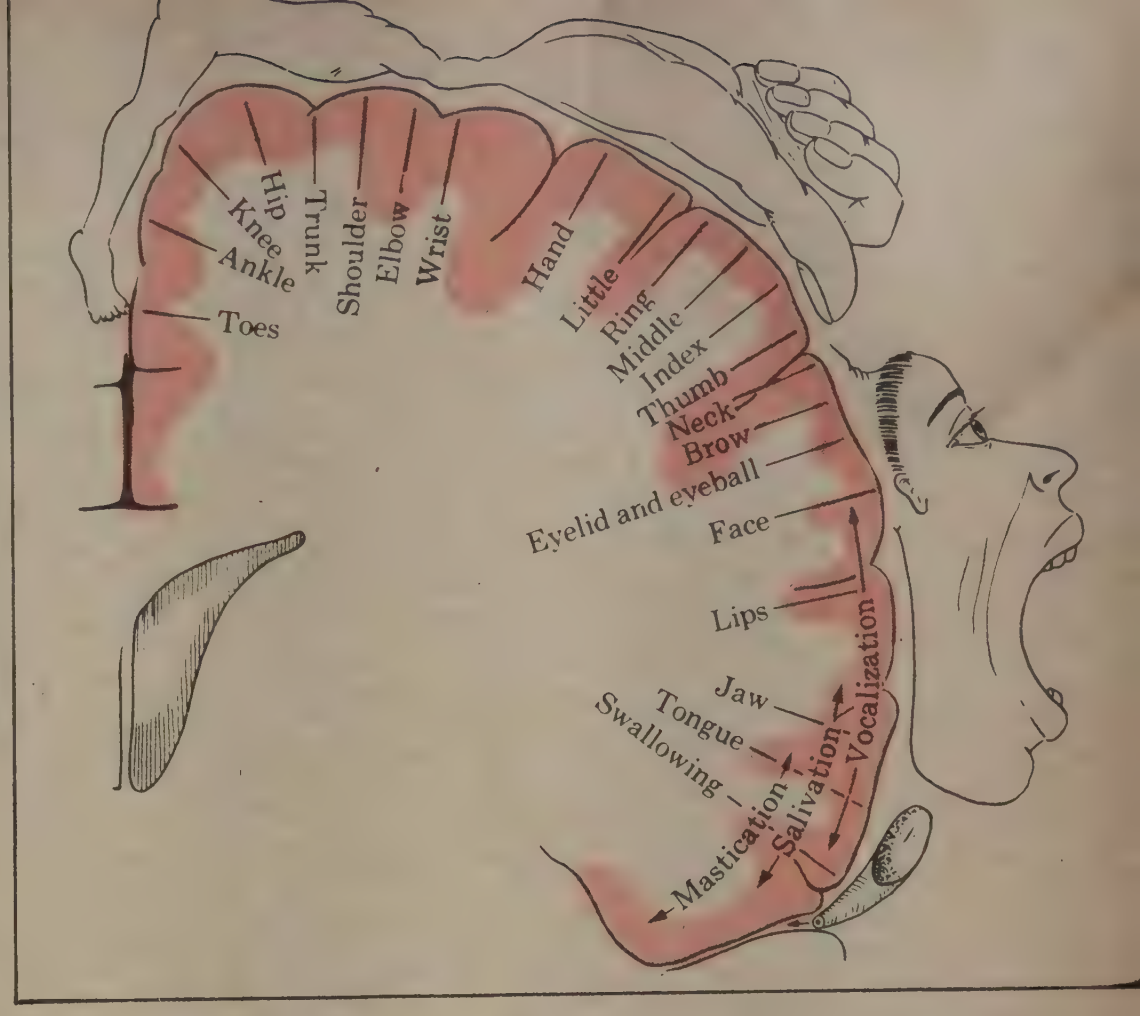
With increasing interest in asso tive conditioning at the turn of 20th century, it was natural psychologists to examine the eff of cutting nerve connections on lea responses. S. I. Franz (1907) perhaps among the first who combi psychological testing with neurosu cal lesions. Experimenting with and monkeys he found that, with destruction of frontal lobes, " recen formed habits were lost although lo standing habits were not affected Lesions in other parts of the cor did not have this effect. Franz co cluded that frontal lobes are employ in the formation of simple associatio

The Harvard psychologist K. Lashley and his students carried a series of brain ablation experimen on rats to determine the role cortical connections in memory st age. They found that extensive cu in the cortex do not impair perfor ance in mazes. When large pieces cortex were removed, it appeared th the retardation in the learning complex mazes was proportional the mass of cortical tissue destroy but relatively unrelated to where t cut was made. This is Lashley's s called ' Law of mass action '. Lashl also found that for the type of tests use by him, a given cortical area cou serve two different functions and, co versely, the same function could carried out by different parts of th

Fig. 9 The neurons in the cortex of a child continue to branch and form new connections in early years







. 10 Well-defined areas of the human cortex control sensory
d motor behaviour. The numbers in the figure on the left are
nventional designations of cortical areas. The figure on the
ht shows a section of the motor cortex depicting the
ationship of particular regions to voluntary movements. A
ge part of motor cortex is devoted to mouth parts and hands

ortex ('Law of equipotentiality'). xperiments rather similar to those f Lashley on localisation of dis- iminative memory have been carried ut with octopuses (by Boycott and thers). Here, too, memory, somewhat ke the Almighty, seems to be 'every- where but nowhere in particular'.

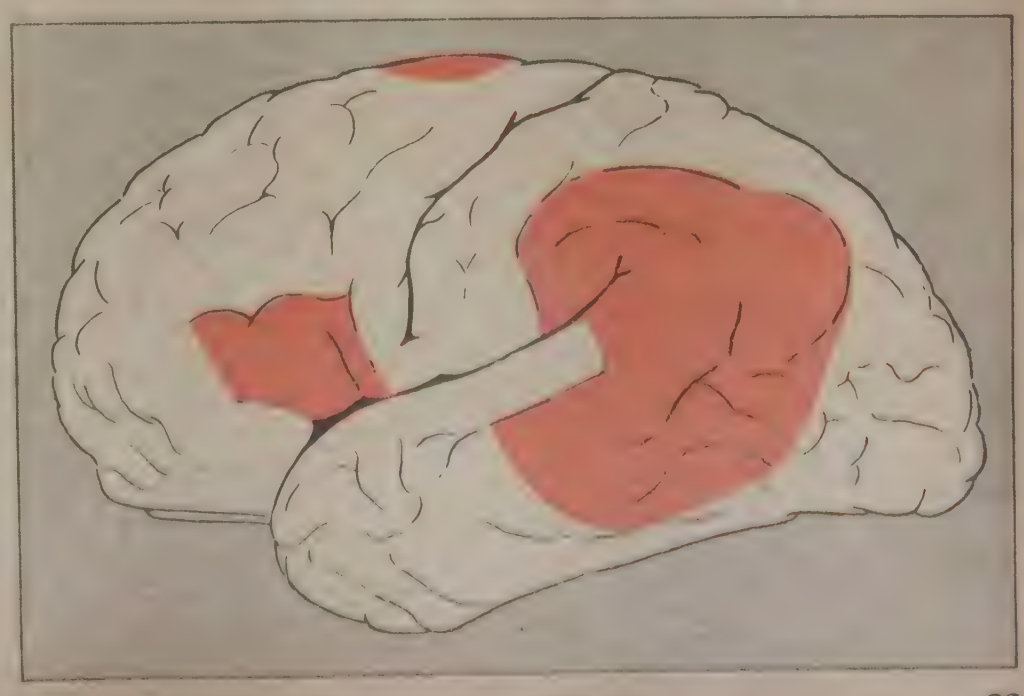
The principles of "equipotentiality" nd "mass action" as demonstrated n maze learning by rats, may or may ot be applicable to human memory. s long ago as 1876 Ferrier had emoved the entire frontal lobes of nonkeys and shown that the animals etained appetites, instincts, sensory bilities and motor faculties. Yet he oted a subtle change of behaviour scribable to loss of attentiveness and ntelligence. C. F. Jacobsen found that esions covering both sides of the rontal association areas of monkeys ompletely blocked the ability to arry out delayed response tests, vhere the animal has to recall an nvironmental cue from memory. After the operation the monkey is nable to remember under which of wo cups food is concealed. At the ame time his performance in other roblem boxes or visual discrimination ests is not affected. The interpretation f ablation experiments is beset with numerous difficulties and one has to eware of accepting simple inter- retations.

I will now briefly discuss some work on the cortical ocalisation of speech which appears o me significant in relation to the roblem of memory storage. The French neurosurgeon Paul Broca examined the brains of many patients who had developed speech defects. He found that these patients very often suffered from damage to brain cells in an area located along the side of the dominant left hemisphere. Broca concluded that this was the speech area. [See Fig. 1 in Prof. Narasimhan's article, p. 28).] It became the prevalent practice to carefully avoid incisions in Broca's speech area during tumour surgery. Wilder Penfield, working at the Montreal Neurological Institute, suspected that not all of the large left cortical area assigned by Broca to speech was really so. He therefore decided to carefully map the speech area by electrical stimulation techniques.

The method used by Penfield was an extension of the technique that had been successfully employed to map the sensory and motor areas of the cortex. A stimulating electrode was placed in the cortex and the patient was engaged in a conversation while being electrically stimulated. When the electrode entered the speech cortex, the stimulus strongly interfered with speech in a remarkably characteristic way. On being asked to name an object in a picture, the subject would say, "Oh! I know what it is, that's what you put in your shoes". If the stimulating current was switched off, he said, "Foot". There was no interference with the control of speech organs. The patient knew what he wanted to say, yet he could not somehow get the right words. This experience is extremely baffling for the patients. They feel frustrated at not being able to find the words they are certain they know and they try to get the nearest synonymns. After the stimulation was stopped, a patient remarked, "I couldn't get that word 'butterfly' and then I tried for 'moth'". This effect is quite different from the effects of interference in areas of motor cortex controlling speech organs. Stimulation of speech motor areas causes slurring or distortion of words or sometimes simple vocalisation, that is to say, emission of long-sustained vowel sounds.

Using electrical stimulation methods Penfield and his associates were

Fig. 11 Speech areas mapped by Penfield



able to map out three clear areas in the cortex (Fig. 11). The three speech areas, as a rule, are located in the left hemisphere. Contrary to expectation, this is also true of patients who are left-handed. There are no significant differences in the speech disturbance produced by stimulation in these areas.

Clearly marked speech areas in the cortex are of obvious significance from the point of view of localisation of memory circuits. Language is an entirely acquired function. Learning a new word is a special experience for each person. The existence of distinctive regions in the cortex that are devoted to speech might, therefore, throw light on neural organisation of long-term storage.

Penfield found that occasionally some of his patients had their speech areas in the right hemisphere. These invariably turned out to be people who had suffered brain damage in the left hemisphere early in life. The organisation of the speech cortex thus exhibits a certain degree of plasticity, but this plasticity does not extend to adulthood. Those who suffer head injuries later in life are not able to transfer their speech functions to the right hemisphere. Some patients who had received extensive injuries in speech areas in the past had transferred their speech functions to neighbouring healthy regions of the cortex.

In addition to plasticity, the speech areas of the cortex also display obvious redundancy. Excision of one of the three results in transfer of speech functions to the other two. Penfield found that he could completely remove the upper of the three speech areas without causing more than a temporary disturbance in speech. He could also make incisions completely encircling these areas without any serious effects, showing that the connecting links between the three areas did not go through the cortex. This conclusion is supported by direct anatomical observations. Each of the three speech areas sends tracts of nerve fibres downwards to the thalamus in the brainstem. (Patients who develop *thalamic* tumours also sometimes suffer from characteristic speech defects.) These fascinating studies are described in a very readable book, *Speech and Brain Mechanisms*, by Penfield and Roberts.

While exploring the human cortex with stimulating electrodes, Penfield made another startling discovery. Electrical stimulation would sometimes induce a patient to recall past events with great vividness. These ordinary incidents which the subjects had experienced and had no particular reasons to remember were suddenly forced by the electrical stimulus on their consciousness. The first patient recalled an early childhood episode with a naturalness as if she was reliving the incident. A young man saw himself with his cousins in South Africa; he felt he could hear them talking and laughing. One woman heard the voice of her son in the backyard, another the singing of the Christmas choir in a church in Holland. These elicited experiences appear very real to the patients and are described in great detail. The vividness of these recollections differentiates them from ord memory; yet the subjects at the time know that they are in the o tion room. When questioned wards, they describe experiencin different awarenesses at the same Penfield calls this " double cons ness ". Sometimes the electrica mulus starts a narrative whi interrupted by shutting off the trode. If the stimulus is renewed same experience starts again a beginning.

Penfield's experiments on ele ally-triggered recall have beer peated in other laboratories. cortical " recall areas " are con to the two temporal lobes on lower left and right sides of the b The fact that the temporal lobes the only areas in the cortex w electrical stimulation causes reca experience need not of course m that this is where the actual mem is located. It is possible that induced signals are conducted to s other part (or parts) of the b where memory traces (whatever are) are stored. It could be that memory traces are not in the co at all, only the cortical access a are localised. Just what these rem able observations mean, we do yet understand; we are neverth left with an inescapable impressio orderliness in the neural organisa of memory.

Roger Sperry and his associate the California Institute of Technol have carried out a series of v remarkable experiments on the called split-brain animals which th

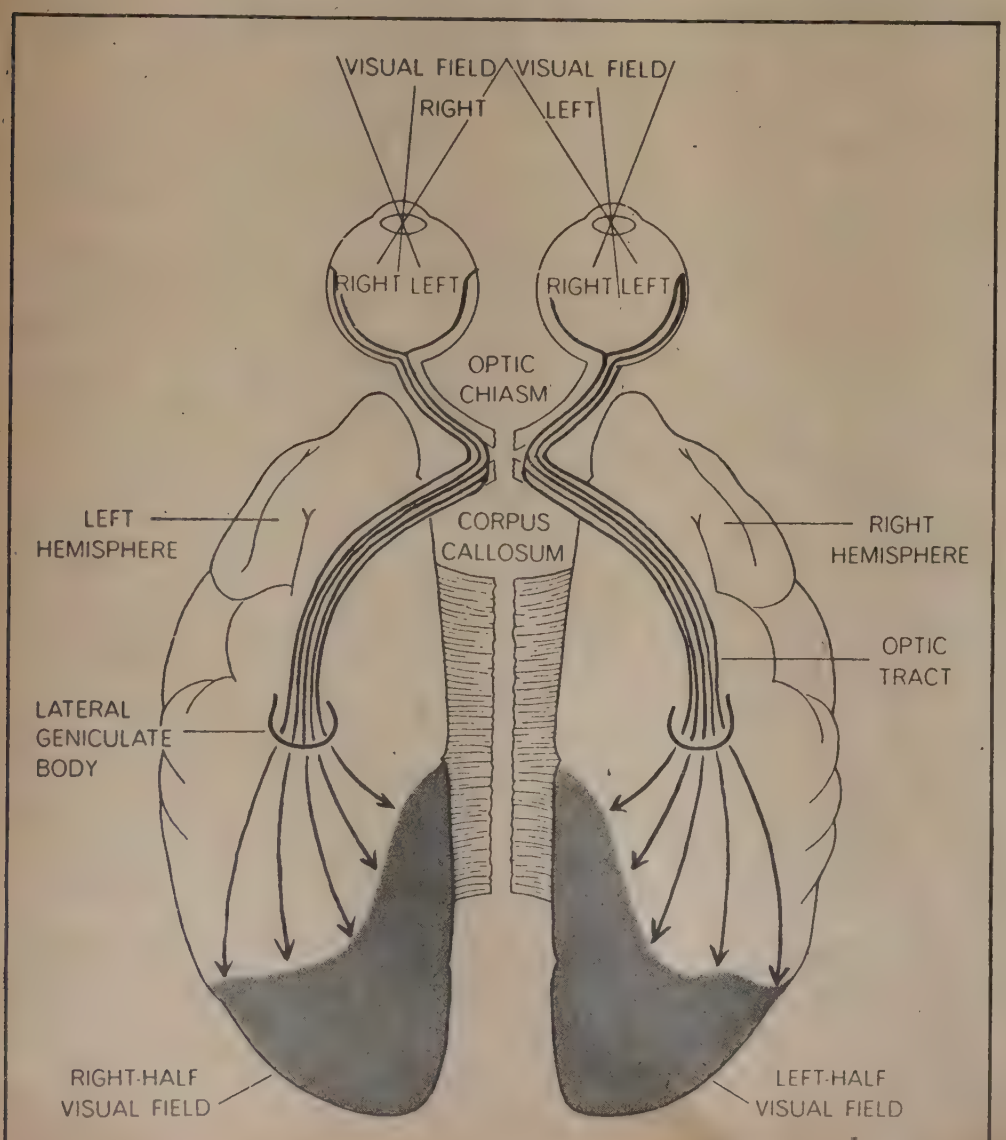
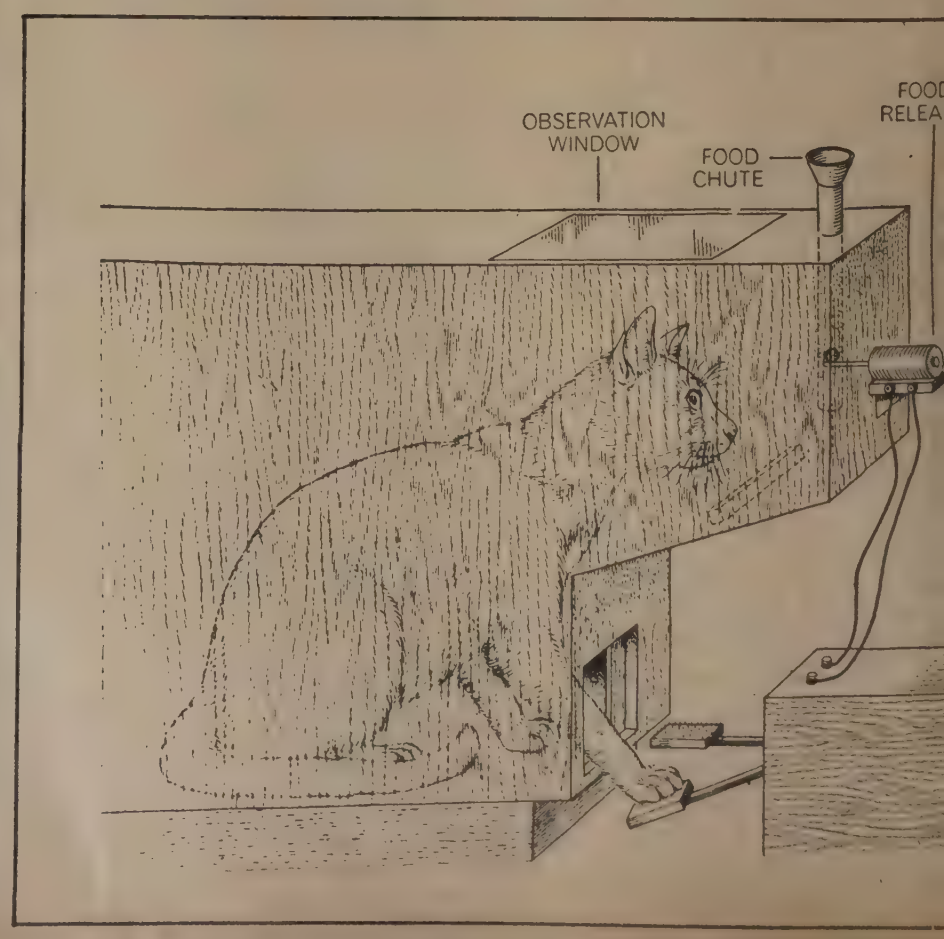


Fig. 12 The two halves of the cortex can be disconnected (split b by cuts in the optic chiasma and the *corpus callosum* (left). Th (below) is trained to obtain food by pressing an appropriate pedal one or the other of its feet. A split-brain cat cannot transfer its lear from one foot to the other



teresting light on the issue of cortical calisation of discrimination memory. ats can be trained to open a door in sponse to a visual cue. The chosen attern, a circle or a square, is dis-layed on the door and, on opening , the cat either receives a reward ood) or punishment (admonition) epending upon the correctness of the noice. Within about 40 such trials, normal cat learns to make correct noices nearly all the time.

The nerve fibres going from the wo eyes to the brain are shown in ig. 12. At a point in the optic tract alled the optic chiasma some of the bres cross over to go to the other de of the brain. Each eye is thus onnected to both the right and the ft hemisphere. The nerve fibres at ne cross-over point can be cut in the anner shown in the figure. In such hiasma-sectioned animals, the in-ormation from the right eye is avail-ble to the right side and from the ft eye to the left side alone. Sperry aught chiasma-sectioned cats the isual discrimination task with one ye, the other being closed with a atch. The patch was then shifted to ne trained eye and the cat's discri-ination tested with the untrained ye open. The cats performed quite orrectly showing that the lessons earnt through one eye were available o the other. The two halves of the ortex are connected together by a nick tract of fibres called the *corpus cal-sum*. If the discrimination learning was ndeed stored in the cortex, the *corpus allosum* could be the pathway along which it was transferred from one side o the other. Sperry, therefore, cut the *orpus callosum* before training the cat. He found that such cats, trained with ne eye closed, could not perform the rescribed task through the other eye. *allosum-sectioned* cats could be trained o open circled doors through one of heir eyes and squared doors through ne other. Their performance in the iscrimination test always corres-onded to the training received by ne eye which was used. C. B. Trevar-hen, one of Sperry's colleagues, has evised a special pair of spectacles for ats so that, in polarised light, they e a circle with one eye and a square ith the other at the same time. Such ats can be taught opposite dis-riminations simultaneously. The cat oes not merely have two disconnected alves of the cortex, there are indeed wo cats in one.

The significance of Sperry's experi-nents for memory storage is this : the nemory traces for the visual discrimi-nation task must be in the cortex nd not, for instance, in the brainstem, s severing the *corpus callosum* makes he discrimination memory non-ransferable to the opposite side. With the *corpus callosum* intact, the memory traces are laid down in two copies, one on each side, so that if the two halves of the cortex are severed after training, the cats trained through one eye can discriminate correctly with either of the eyes open. Jan Bures of the Czechoslovak Academy of Sciences has shown that if conduction of nerve signals along the *corpus callosum* is blocked during training, transfer of memory from one side to the other does not occur after the block is removed and only one copy of the memory remains. Sperry and his associates have extended the split-brain experiments to other animals including monkeys and humans and employing other sensory modalities such as touch or hearing. In certain experiments they were able to remove large parts of the cortex and thus ' corner ' the memory traces for tactile discrimination to the sensory-motor area. In comparable experiments with rats, Bures has obtained evidence for localisation of visual discrimination memory in the region of visual cortex. In either case, some of the discriminative memory traces seem to be laid close to the area of the primary sensory modality that was employed in learning the task.

Fig. 13 Neuronal pathways can be located by injection of fluorescent dyes. The coloured photograph shows the branching out of the dendrites in a section of an insect brain. Such techniques are now beginning to be used in the study of the neuronal network of mammals

From the experiments described above, it would seem that the brainstem did not actively contribute to memory, but this is not always the case. When learning involved the simultaneous use of two different sensory modalities such as visual and tactile, the memories stored in the two halves of the cortex, which are not transferable from one to the other, could be integrated. This obviously requires the participation of the brainstem. There are many other implications of the studies on split brains which go beyond the scope of this article. There is a fascinating account of the experiments on human split-brain patients by Gazzaniga in the book *Bisected Brain.*

From the point of view of localisation of memory, the answers that emerge are clearly not simple. The plasticity and redundancy of connections in the brain made it difficult to obtain evidence of localisation in ablation experiments of the type done by Lashley. Connections are formed during learning that join more than one part of the brain into a learning

system which includes not only the cortex but also other parts of the brain. The system is not easily disrupted because of its distribution and parallel connections. Memory may nevertheless be localised in that the firing of particular groups of cells in this system might correspond to activation of a specific memory.

A somewhat different way of looking at memory is to conceive of it as a coherent pattern of activity in a volume of cells in which the set of cells contributing to the pattern might change. In this system, different items of information need not be coded by different cells. The emphasis, in the second view, is on the activity pattern and on the fact that a cell may participate in more than one such pattern.

The two ways of thinking about memory connections are not mutually exclusive and the actual situation probably represents a combination of the two. Clearly, the naive pictures of functional localisation reminiscent of early phrenology cannot be entertained. At the same time the evidence points towards an orderly organisation of discriminative memory.

Sushma

Drawing based on Rodin's famous sculpture 'The Thinker" with the head borrowed from Vesalius's sketch (in Fig. 1, p. 16)

Biochemistry of memory

In recent years there has been a great spurt of research activity aimed at discovering the molecular mechanisms responsible for the formation of memory traces. The *raison d'etre* of this field seems to be the observation that the electrical activity of neurons is accompanied by a large increase in RNA (ribonucleic acid) and protein. Just as the structure of proteins is coded into the base sequence of DNA or its transcript, the RNA, some have argued that memory may be coded into a special type of RNA. The base sequence of this RNA is determined by the electrical activity of nerve cells. To quote Hyden, one of the early proponents of the RNA theory:

" The modulated frequency generated in a neuron by specific stimulation is supposed to affect RNA molecules and to induce a new sequence of nucleotide residues along the backbone of the molecule. The new distribution of components will then remain; the RNA has been specified. This leads also to a specification of the protein being formed through the mediation of RNA.

" By a combination of this protein with the complementary molecule, the transmitter substance at the point of contact with the next neuron, at the synapses, is activated. This allows the coded information to pass on to this next neuron."

It is not obvious how these various things happen. One can only say that, if this theory is true, it calls for the creation of a radically new molecular biology in addition to a new neurophysiology. All that Hyden observed was that, as a result of electrical activity in neurons, either in a learning situation or in situations somewhat analogous to it, the chemical composition of the cell's RNA changes.

Others have argued that RNA sequence *per se* need not be governed by electrical activity but the electrical signals could ' switch on ' the activity of certain genes to synthesise a special type of RNA. This RNA might work as an inducer of nerve connections and might be passed from cell to cell.

Yet others have maintained that it is not RNA but protein that is the thing. They have concentrated their energies on detection of new proteins correlated with the activity of nerve cells, specially during learning. Such proteins have been identified in the brains of fish and mice and at least one of them has been the subject of detailed structural analysis.

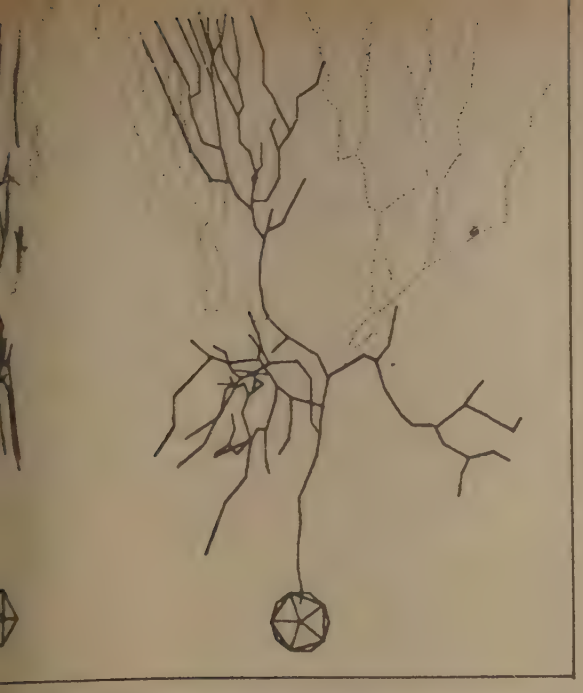
The brain cells are metabolically among the most active cells in the body and there is no significant c pound in these cells that does display a remarkably high rat turn-over. That increased elect activity of nerve cells is accompa with synthesis of RNA and pro is not surprising and does not te much about the part these m cules play in learning and mem If two things happen at the same ti this is never, by itself, sufficient rea to believe that one is the cause of other.

More direct evidence in favou the RNA-protein theory of mem has been presented in claims t compounds such as puromycin cyclohexamide that inhibit synth of RNA and protein block consoli tion of memory. A goldfish trained perform a simple task when injec with cyclohexamide in its skull is s to forget what it had been taug Conversely, facilitation of RNA s thesis is believed to reduce the ti needed for consolidation. It has b claimed that RNA helps in storage and retrieval of informati The faith in RNA indeed seems strong that some have actually ministered massive doses of ye RNA to rats and found that injected RNA markedly improved memory of aged individuals.

The most dramatic claims favour of RNA-protein theories memory come from experiments volving transfer of memory along w brain extracts from one animal another. The stage for this branch memory research was set McConnel and his colleagues w their work on planarian flatwor Planaria were conditioned to respo to light flashes. The condition worms were chopped and fed naive worms. The cannibali worms, it was observed, learnt light response more rapidly than th naive brothers. Treatment of worm-chop with an RNA-degrad enzyme prevented the transfer learning ability. McConnel's expe ments were publicised several ye ago by the popular writer Arth Koestler and received a great deal attention.

In the same vein, ability to le a variety of conditioned responses believed to have been transfer along with extracts made from brains of trained rats and mice with RNA or protein in these extra injected into untrained recipients.

Not much need be said about th experiments. There are about as ma who have failed to confirm the exp ments and to obtain any evidence favour of transfer of memory injecting brain extracts, as there those who have succeeded. The en



14 Computer-aided electron microscopy be employed to reconstruct three-dimen-al views of neuronal branching. In the ure above, the computer displays two vs of a reconstructed nerve cell (the figure he left shows the figure on the right after as been turned by 90°)

d of chemical memory transfer is troversial and not particularly minating.

ture prospects

If I have left you h the overwhelming impression t nothing is known about bio-ical mechanisms of memory, I ould like to end this article with ne degree of optimism. It is true t, at present, not much can be said h certainty, but there are a few eresting things that we do know. om the experiments of psycho-ists we know the chief character-cs of memory that have to be plained and we have learnt a good al about how nerve cells work. e can, therefore, have a better preciation of the problem itself. ethodologically speaking, we are o in a better position to attack the oblem. This is why, I believe, the dy of memory mechanisms is going be more exciting in the future than the past.

It is not very easy to devise good periments to study the physical aracteristics of memory traces. The oss-sectional area of an average uron is one hundred-millionth of square centimetre. It is hard to ake microscopic observations on naptic changes or to analyse de-iled electrochemical properties of a uron before and after learning. In ct, it is quite difficult to locate *neuron* among billions of other urons in the brain of animals.

But difficult, in science, is never to construed as impossible. A number recent advances in methods of urobiological research makes it likely at the undoable will be done. We w have experimental methods by hich, with the help of minute electrodes, electrochemical changes in single neurons can be monitored. Micropipettes can be used to inject fluorescent or electron-opaque dyes in nerve cells enabling us to visualise the ramifications of dendrites (Fig. 13). Electron microscopy aided by computerised analysis can help us reconstruct neuronal trees in three dimensions with the fullest details of their synaptic organisation (Fig. 14). Powerful methods are available to trace out the connections that neurons in one part of the brain make with other parts and to study the development of these connections.

We are becoming increasingly aware of the fact that the problems of brain function have to be approached from many sides. A many-sided attack on the memory problem, combining methods of biology and psychology, can be best made in experimental animals that lend themselves well to the requirements of either approach. A great deal of exploratory work in search of such model systems for studying brain functions is currently going on. Biologists have a deep conviction in the unity of life and most of us would be willing to bet heavily on the proposition that what we might learn from crabs, flies and cats will apply to other animals including man.

The problem of memory is not one of finding a single key answer to a single question, either on the matter of its location or of its special biochemistry. The real problem is to understand how neural circuits acquire the ability to restructure themselves in response to everchanging environmental inputs. The explanations we give must account for well-established properties of memory uncovered by experimental psychology. As perceived by Quintillion nearly 2,000 years ago, memories are formed by association with previously formed memories. Secondly, memories arise in stages, first as highly transient sensory perceptions some of which are salvaged by attention-focusing mechanisms and converted into long-lasting traces. These traces can be strengthened by repetition and weakened by neglect and distraction. These and other similar psychological attributes of memory must be accounted for. At the same time our explanations must be firmly grounded in established principles of molecular and cellular physiology. The problem of memory is closely connected with that of the formation and maintenance of functional neural networks, itself a part of the larger problem of how complex biological structures develop. Molecular biology, or at least the molecular biology of viruses and bacteria, has been principally concerned with how large and complex non-repetitive molecules are constructed. The mechanisms involved are self-contained and fairly deterministically governed by the genetic programme; environmental influences enter only in a peripheral manner, as for instance, in regulating the rates of synthesis.

The developmental programmes of higher animals and plants exhibit an additional and quite novel feature which might be called *acquired variability*. These organisms modify themselves adaptively, often in very remarkable ways, in response to varying biographical experience. Jean Baptiste Lamarck mistakenly made this 'adaptive principle' the basis of his theory of evolution. Notwithstanding this misapplication, adaptive assimilation of environment must confer upon the organism great advantage to have been cultivated so assiduously by natural selection.

The mechanisms that underlie adaptive responses of multicellular organisms are just beginning to be explored. A nervous system that permits systematic modification of neural circuits in response to experiential inputs, with its concomitant memory, exemplifies the Lamarckian principle in its most sophisticated form. Memory, from this point of view, has nothing to do either with the intractable activities of a conscious soul or the passive storing of a magic molecule; it is a high biological achievement.

Professor of Molecular Biology at the Tata Institute of Fundamental Research at Bombay and Head of its Molecular Biology Group, Prof. O. Siddiqi (45) took his MSc from Aligarh University and PhD from the University of Glasgow. He worked at the Cold Spring Harbor Laboratory, NY, the University of Pennsylvania and the Laboratory of Molecular Biology at Cambridge before joining TIFR in 1962. Prof. Siddiqi's contributions are in the area of molecular genetics and genetic neurobiology. He was Visiting Professor of Biophysics at MIT and Gosney Fellow in Behavioral Genetics at the California Institute of Technology. Fellow of the Indian National Science Academy and also the Indian Academy of Science, he was awarded the Bhatnagar Prize for Biological Sciences in 1976.

Memory and Language Behaviour

R. NARASIMHAN

"What is the height of Mount Everest?"

"I don't remember the exact height. But I think it is about twenty-eight thousand feet."

All of us are involved in conversations of this type throughout our adult life. But I doubt whether most of us ever pause to wonder about the nature and complexity of the neural machinery that enables us to engage in such conversational interactions. In order to delimit the problem somewhat more narrowly, suppose we want to build an automaton — say, an 'intelligent' computer — that can engage in conversations of this kind. How would we go about designing such an automaton? What kinds of capabilities do we have to build into it? Clearly, it must go through at least the following minimal operations: (1) The incoming acoustic signals must be analysed into speech units and the sequence of speech units interpreted as meaningful English language fragments; (2) Realising that the input is a question, it must be understood as relating to some identifiable part of the (internally available) knowledge of the world; (3) Based on the interpretation of the nature of the query and the internally available information, an appropriate answer must be determined; (4) Finally, a speech response must be generated incorporating the answer that has been determined. Thus, we need a speech analyser and a speech generator at the input and output ends; and, in between, a suitably encoded world-knowledge store coupled in some way to the analyser on the one side and the generator on the other.

Compare the above design outline with this account of what a neurophysiologist thinks goes on during the course of such a conversational interaction:

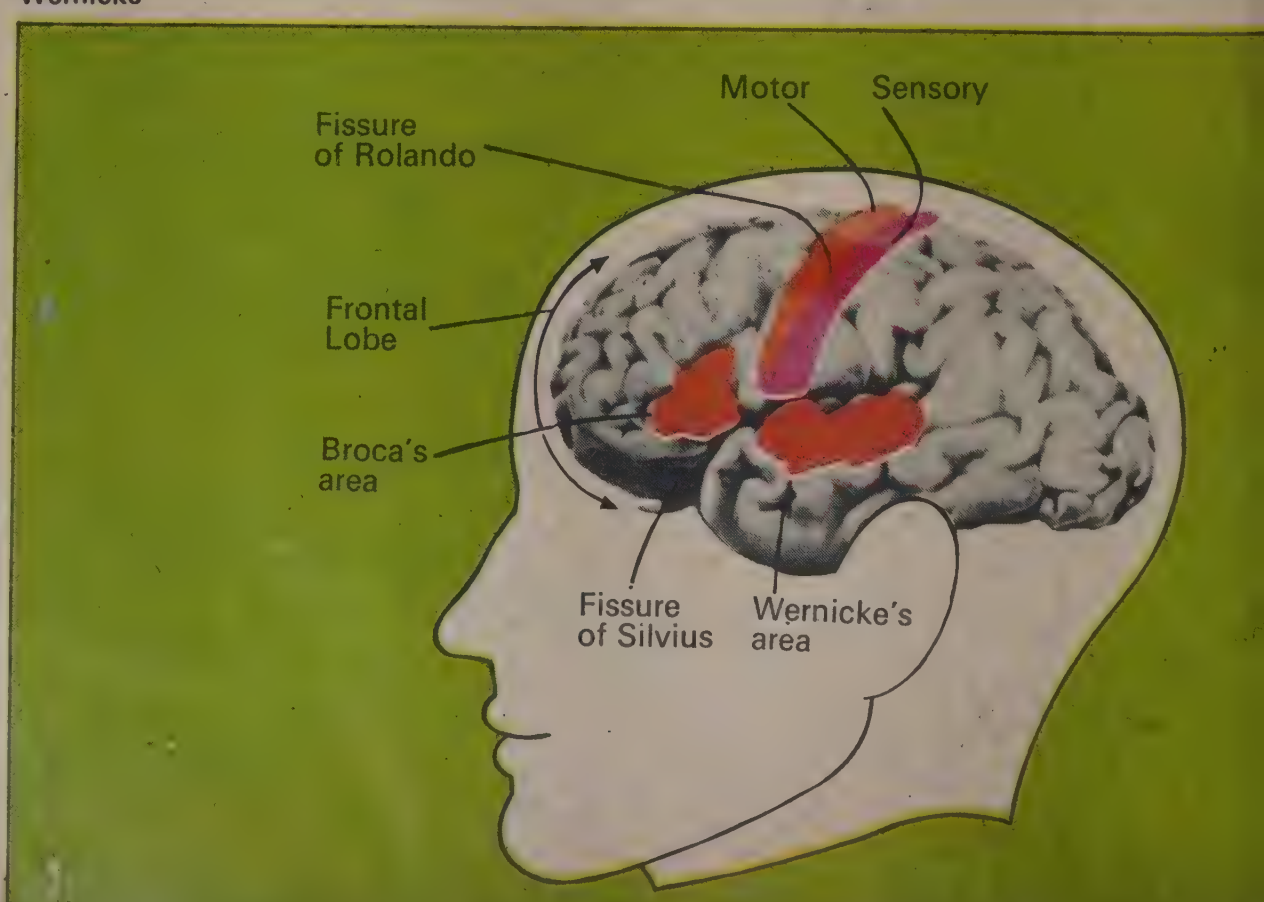
"Listening to speech or reading a book would send a stream of afferent impulses flowing inward over the auditory or the visual route, through the transmission stations of the cortex, into the centrencephalic system. From there the stream must somehow exert its patterned effect upon the speech mechanism of the dominant sphere. Ganglionic counterparts of the words are thus activated in the speech mechanism. As each word complex is thus activated, it wakens, by its own automatic reflex, the corresponding concept. . . . The connection between *speech mechanism* and *concept mechanism* is evidently reflex and automatic. . . . The act of speaking probably depends upon the functional action of the centrencephalic system. It accepts the word patterns from the speech mechanism and sends out a stream of voluntary impulses through the cortical motor stations of voice control or hand control. . . ."

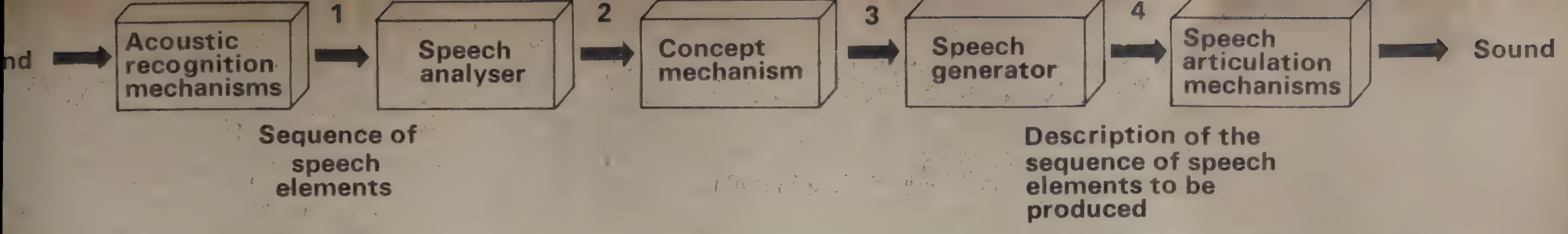
The above quotation is taken from Penfield's description in the book by Penfield and Roberts. The functional units that he postulates — the auditory analysers, the speech mechanisms and the concept mechanism (or concept "storehouse") — are seen to be quite analogous to the engineering counterparts we had earlier sketched for our hypothesised automaton. Intuitively, not only do these design details sound plausible, but it is cult for us — according to our cu ways of analysing the problem see how else such behaviour cou accounted for (or synthesised us computer). Nevertheless, an exp tion along these lines raises problems than it seems to solve. of the new issues raised would to suggest that there must be flaws in the way we tend to appr the problem.

Consider, for instance, the me mechanisms that must underlie neural processes giving rise to guage behaviour as hypothe above. For every language item explanation calls for three int representations: one as the outp the speech analyser, the second a input to the speech generator, an third as part of the concept mec ism. We have no clue as to nature of these internal represe tions and their functional coupl The notion of a 'concept mechan or a 'concept store' is, to begin v a highly non-informative one. W is our concept of a 'chair' o 'Mount Everest'? How are represented inside us? Are all cepts analysable along compar dimensions? Some concepts, 'chair' for example, are pictura But what about concepts 'freedom' or 'grammar'?

The idea that language interact are analysed and understood in te of words (what one might call 'dictionary-view' of language haviour) is known to be quite tenable. Again, there is the prob of *serial order* that has to be accou for, as Lashley pointed out i seminal paper over two decades Human (and also other anir behaviour is highly integrated al

Fig. 1 The left side of the human brain showing the speech areas as mapped by Broca Wernicke





. 2 An engineering model of speech analysis, understanding and generation system. The portant functional units are designated within the boxes. Language disorders of various kinds t have been observed can be related to the malfunctioning at the interfaces labelled 1, 2, 3 d 4 in this model (see text for details). Computer simulation studies of language understanding d usage are based on models of this kind. Current neurophysiological ideas also use similar dels. Nevertheless it is argued in the text that models such as these must be wrong in essential tails

e time dimension. This is especially ue of language behaviour. Speech nnot be understood by interpreting ords one at a time in the order in hich they are received. For instance, nguage is full of homonyms whose eanings cannot be determined with-it the use of contextual clues. Con-der the sound corresponding to right' as it occurs in this example om Lashley's paper: "The mill-right on my right thinks it right that me conventional rite should sym-olise the right of everyman to write he pleases". In speech the con-xtual clues may be scattered over wide temporal interval. Computer mulation studies based on models of e kind we discussed earlier show at the processing aspects needed cope with context, presupposition, c could become extremely complex. ut in real life these problems do not em to pose excessive difficulties. This ould seem to indicate that our odels do not mirror in essential etails what goes on in our neural stems in using and understanding nguage.

To avoid any possible confusion should perhaps emphasise that roughout this article I restrict my nsiderations to the naive, conversa-onal language behaviour of normal uman beings. As you may have uessed from the discussions so far, e neural mechanisms that support nguage behaviour are not restricted memory. In fact, when one deals ith complex behaviour, such as that volved in using and understanding nguage, it is very difficult to isolate e role played by memory and study as if memory were a well-identifi-ble, distinct unit. As we shall discuss detail later in this article, we should ot think of memory as a passive store. rocesses associated with memory recalling, remembering, recognising) re active, creative processes. Such rocesses enter into language be-aviour in complex ways which we nderstand very little at present.

The standard procedure for con-tructing theories or models in science to collect data on the basis of con-rolled experiments, to hypothesise bout the structure, function and ynamics of underlying machinery that could account for these data, and then to perform further controlled experiments to test these hypotheses in various ways. Unfortunately, such standard procedures are unavailable for our use in the study of language behaviour. Language behaviour is exhibited only by human beings and it is not possible to perform on them cortical ablation experiments of the kind that neurophysiologists have been performing on animals to study brain structures that underlie behaviour in the various modalities. [See Dr. Siddiqi's article (pp. 15–27) for descriptions of such experiments.] We have to base our studies exclusively on brain disorders that occur naturally, or on brain damages that are accidentally produced, for example, due to head injuries in war. In the last 100 years, a very large amount of data bearing on language behaviour has been collected from such studies. I shall try to briefly summarise here our present state of knowledge in this area. Unfortunately, this knowledge does not give rise to any coherent picture of the neural mechanisms that underlie our ability to use and understand language.

Language disorders

"Aphasia" is a generic term used to describe language disorders of many kinds. Language disorders must have been known and observed for a long time. But it was only in 1861 that Paul Broca presented to the Anatomical Society of Paris two cases of elderly persons with loss of speech and surmised for the first time that their speech deficiency was due to cerebral injury to a specific region in the left frontal lobe. This region is now conventionally designated as Broca's area. In 1874 Carl Wernicke, a clinical neurologist working in Breslau, published a monograph on aphasia at the age of 26 with the title, "The Symptomcomplex of Aphasia: A Psychological Study on an Anatomical Basis". In this work he identified a second region in the cortex (which is now conventionally referred to as Wernicke's area) injuries to which gave rise to language disorders of a kind different from those that Broca had described. Wernicke referred to this variety as 'Sensory Aphasia' and distinguished it from the 'Motor Aphasia' of Broca. Wernicke's work is of great historical importance because it started a new trend in the study of aphasia: "a clinical-neurological approach in which an attempt was made to relate the patterning of symptoms of speech disturbance to the location of lesions in the brain". In the succeeding decades, Wernicke's students and followers made 'diagram-making' (of the brain) into an industry, inevitably generating a back-lash of criticism and antagonism to this approach. Hughlings Jackson (later 19th century) and his student Henry Head (early 20th century) in England, Marie in France, Freud, and others in more recent times like Goldstein, were vocal critics of the diagram-making approach and argued for a more holistic framework. Nevertheless there are eminent clinical neurologists who continue to espouse Wernicke's theoretical ideas; Norman Geschwind is perhaps the most persuasive of these.

In the 100 years since Broca and Wernicke, an enormous literature has accumulated on aphasia. Neurologists, neuro-psychologists, anatomists, physiologists, clinical psychologists, linguists, psycholinguists, have all had their say, have attempted to classify aphasia into various categories, and have tried to theorise about them. In the last two decades, several interdisciplinary conferences have been organised bringing together all these specialists in the hope that a coherent picture of aphasia could be drawn out of their separate studies. Writing in 1890, William James expressed this hope: "Meanwhile few things show more beautifully than the history of our knowledge of aphasia how the sagacity and patience of many banded workers are in time certain to analyse the darkest confusion into an orderly display". Alas, a hundred years of patient work by 'many banded workers' has not yet begun to dispel our 'darkest confusion'.

After going through many of these interdisciplinary discussions and published papers, I find that, perhaps, the simplest way of summarising the generally prevailing views on aphasia is to relate them to the hypothetical automaton design that I outlined at the start of this article. That design, you may recall, called for a concept

mechanism coupled to a speech analyser at one end and a speech generator at the other end. This, then, gives rise to four functional interfaces: (1) going from the acoustic signal to speech analysis; (2) the coupling between the output of the speech analyser and the concept mechanism; (3) the coupling between the concept mechanism and the input to the speech generator; and (4) going from the speech generator to the articulation mechanisms of speech.

These four interfaces can give rise to four broad categories of disorders. The first of these is really concerned with the hearing mechanism and is not specific to language behaviour. So, we shall not deal with it any more here. The fourth category of disorder is called *Dysarthria* or *anarthria* and shows up as a difficulty in the "voicing" of speech. In this sense, this, too, is not strictly a language disorder.

The other two are truly language disorders: the second corresponding to Wernicke's sensory aphasia, sometimes called decoding disorder. But it is perhaps more accurate to refer to this class as *receptive disorders*. The third corresponds to Broca's motor aphasia, sometimes called encoding disorder. Again, this class is best referred to as *expressive disorders*. Published literature subdivides these two classes into a variety of more specialised categories. But it is really very difficult to justify these subclassifications on convincing analytical grounds. Attempts to relate them to injuries to specific areas of the cortex have not found general acceptance. I shall now briefly describe the behavioural aspects of the language disorders belonging to these two broad classes. More detailed accounts may be found, for example, in the book by Penfield and Roberts, or in Lenneberg's book *Biological Foundations of Language*. There is also a detailed review report by Osgood and Miron which contains an extensive bibliography and details of clinical tests used in aphasia studies.

Receptive Disorders: The patient exhibits a marked inability to recognise or make sense of spoken language. This is not due to lack of attention or deficiency in hearing. The patient clearly realises that he is being spoken to and is expected to respond. But he finds he is unable to make sense of the speech sounds he hears. Somewhat paradoxically, although the patient may spontaneously use certain words and phrases, he may not be able to repeat them on command or respond to them.

Expressive Disorders: The ability to respond in the language modality may be disrupted in many distinct ways.

(*i*) Fluency of speech may be severely affected. Patients typically respond in a style that may be called 'telegraphese'. following example illustrates well: "Mary, my Mary, ... Saturday, Clevel wedding. . . . . yes, mar tomorrow, sometime, Sun home, four days . . . . ."

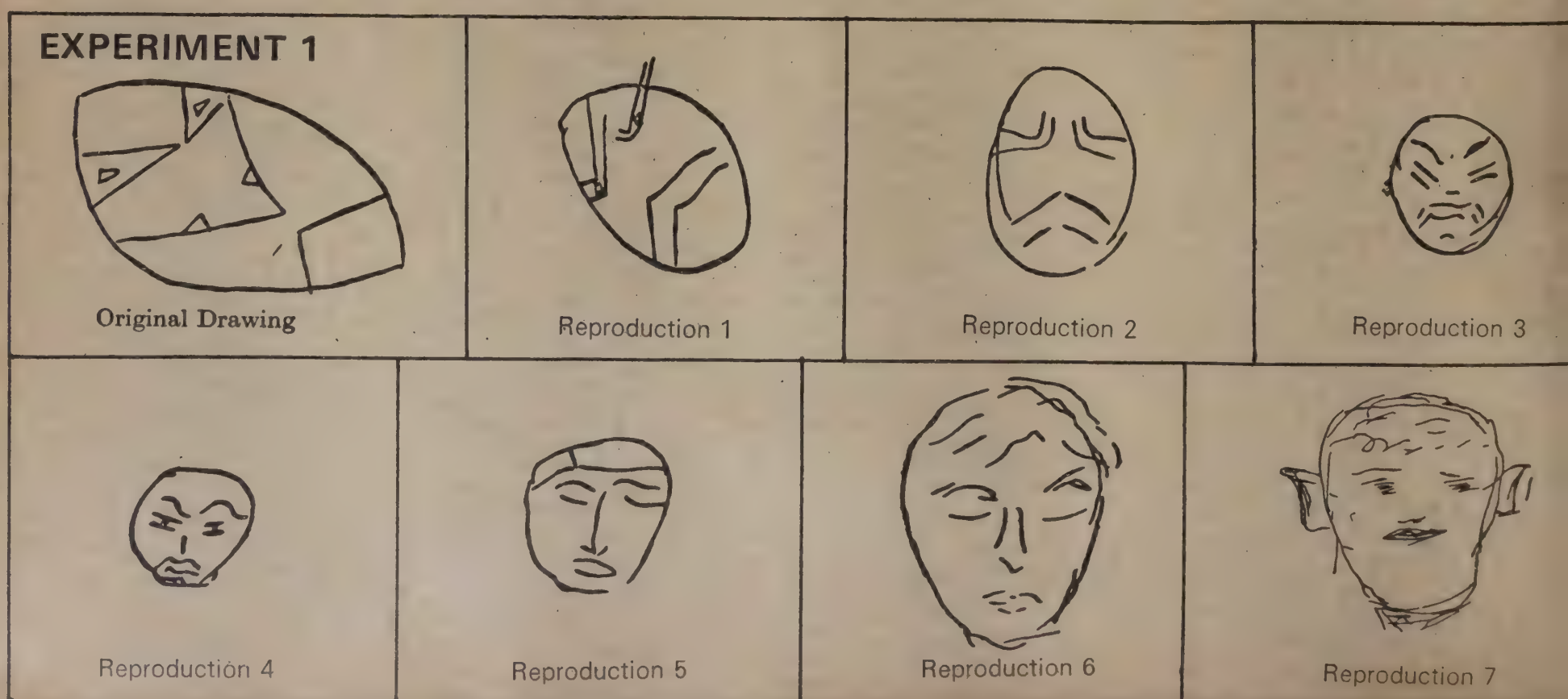
(*ii*) The flow of speech may excessive and uncontrolla Linguistic expressions tum out in a continuous stream do not conform to any gra matical rules or accepted so norms. "The patient jur from thought to thought a topic to topic . . . usually substance of the communicat cannot be understood."

(*iii*) Language usage may be rupted in linguistically m significant ways. For examp there may be an inability name colours or numbers. Na ing of objects may be diffic or impossible. As an examp a patient, when shown a kn and asked for its name, sa "that's a bilk, a bite, yes, me bite". Quite often a patient unable to find a word, b attempts to express himself in roundabout way. Unable name a watch, he may s "used to tell time". Parado cally again, the same patie may quite spontaneously use t word 'watch' by demandi "Give me back my watch!".

Fig. 3 These pictures illustrate the outcomes of two experiments in serial reproduction (see text for definition) that Bartlett conducted using pict material, instead of prose texts. Bartlett comments: "Whenever material visually presented purports to be representative of some common obje but contains certain features which are unfamiliar in the community to which the material is introduced, these features invariably suffer transformati in the direction of the familiar. This constitutes a kind of analogue in the case of picture material to rationalisation in the case of the prose passage

In the first series (below) all the characteristics of the original which have any peculiarity are lost. The face is made vertical, becomes ov then round, acquires eyes, a nose and a mouth, all of conventional form.

The original of the second series (right) is a representation of the Egyptian *mulak*, a conventionalised form of an owl. It can be seen ho accidental errors in recall tend to get progressively rationalised into deliberate details of the picture which are then simplified into conventionalis forms. An owl thus gets transformed into a cat in successive steps!



There are other forms of linguistic turbances which are sometimes erred to as *jargon* aphasia or *agram-tisms*. The following examples illus-te these varieties of disorders: " He speeching it, there and then, aightaway for me, there "; " . . . t I shall have lesson with the ngage of the hear itself "; " Well, I ought thing I am going to the . . . l is about my operation and it is t about all I can tell is about the eparation the had was always the . . . "

Closely related to aphasia are read-g difficulties (*alexia*) and writing fficulties (*agraphia*). There is a vast erature on these ailments also. But would take us too far outside the ope of this article to go into the etails of these.

In a recent interdisciplinary con-rence on aphasia, an American inical psychologist, Davis Howes, ade the following point which I ink summarises well the current ate of affairs in aphasia studies. He id, "Aphasia is often considered om three rather distinct aspects or vels: the anatomical, the physio-gical, and the behavioural or sychological. The extent to which here is agreement on our current nowledge of aphasia seems to differ ery much at each of these three evels. . . . It would clarify matters onsiderably if we were to recognise that the three levels at which we discuss aphasia are really not cognate. Our knowledge of aphasia comes exclusively from the first and the third: the physiological is strictly an inferred level. . . . The confused picture of aphasia that one finds at this level thus signifies that we have as yet no satisfactory *theory* of aphasia . . . . "

Before we leave the topic of aphasia perhaps we should emphasise that the disorders we have been describing do not imply a " loss " of language. As Lenneberg notes: " The patient is not reduced to a state of no language . . . he knows basically ' how language works ' . . . . Neither discrete words nor discrete grammatical rules are neatly eliminated from the store of skills. . . . but some physiological processes relating to activating, monitoring or processing of speech are deranged. . . . "

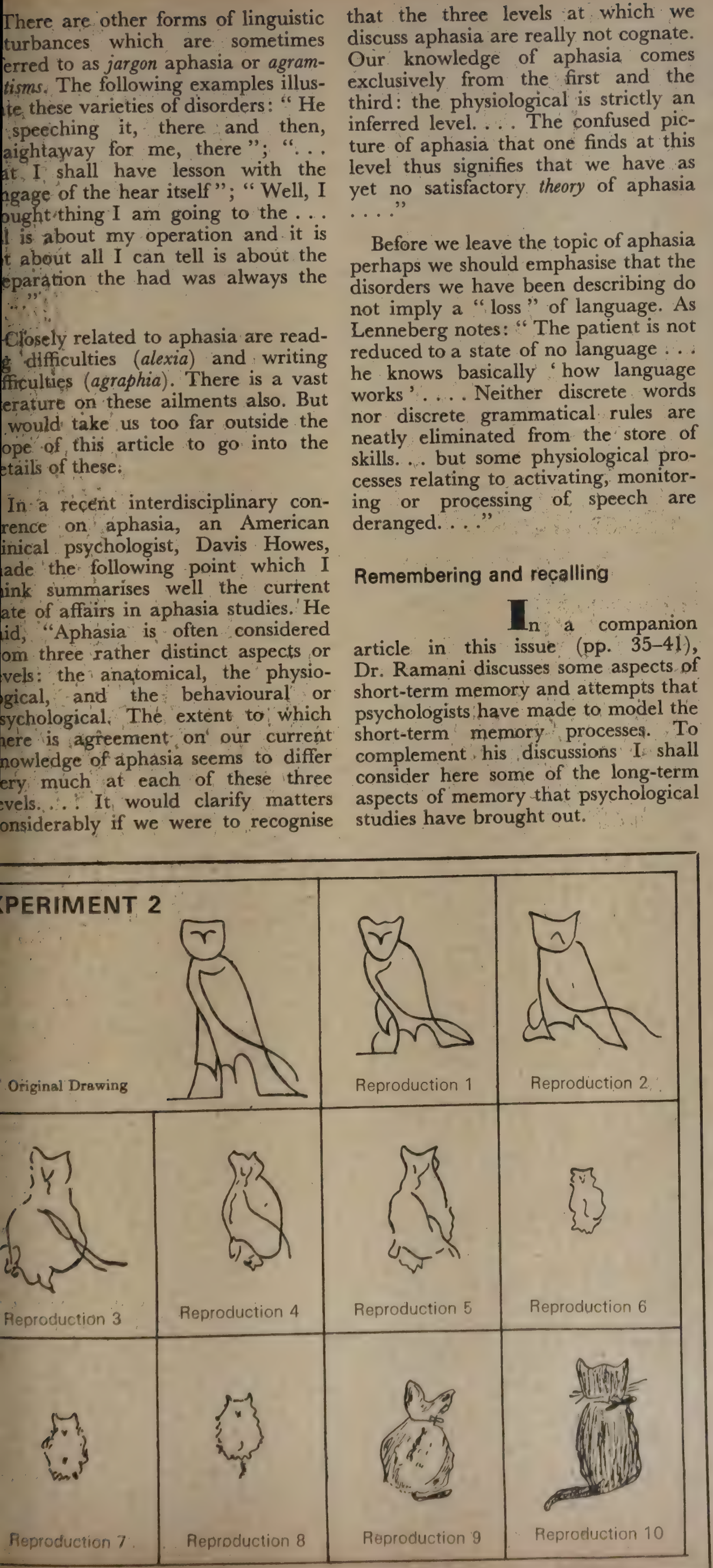
Remembering and recalling

In a companion article in this issue (pp. 35–41), Dr. Ramani discusses some aspects of short-term memory and attempts that psychologists have made to model the short-term memory processes. To complement his discussions I shall consider here some of the long-term aspects of memory that psychological studies have brought out.

To begin with, I should reiterate a point that Dr. Ramani makes in his article. One of the primary problems we face in dealing with memory is that we do not yet have a satisfactory language in which we can talk about behavioural phenomena associated with memory. Our commonsensical ways of referring to memory processes are quite misleading. For example, we tend to look upon ' remembering ' and ' recall ' as somewhat analogous to ' storage ' and ' retrieval '. In a real, physical world we may store information in a book, on computer tapes, in computer memory (or storage); or, we may store material items in cabinets; we may store letters in pigeon-holes. Retrieval, then, is the reverse process. We go searching for an item when in need of it, find where it is stored and retrieve it. But, as we shall see presently, remembering and recalling are not processes of these kinds at all.

' Remembering ' construed as ' storage ' raises, also, other much deeper issues. We remember our experiences; we remember a picture, a face, a piece of music; we remember a word, a name, a variety of language expressions; we remember rules and procedures for solving problems or specific puzzles. In each of these cases, what is it that is stored? In remembering a face, is it something like a photograph of the face that is stored? As the American psychologist Skinner remarks somewhere, supposing this were true, it would not, in fact, solve our basic problem, but raise fresh ones. For, now, we must worry about *who* looks at this photograph stored inside the brain and interprets it, draws inferences from it, and so on. There is now much less of the brain available to do all these!

In the case of language, are individual words and expressions stored in some form? As in a dictionary, for example? Is there only a single entry for a given word, or are there multiple entries? Would it be possible to destroy selectively specific entries, like tearing a page off a dictionary, or destroying a letter in a pigeon-hole? Would that destroy one's capacity to use the particular word or expression, or understand it? We have already seen earlier, in our discussion on aphasia, that highly specific deficiencies of these kinds do not occur. In fact, Penfield asserts that in his brain stimulation studies, " We have found no pigeon-holes in the cortex where words are sorted out. Small removals may be made even in the cortex of the posterior speech area, and small injuries may occur there, with eventual recovery after aphasia. And when command of speech returns to the



individual, there is no special group of words to be learned over again, as would be the case if the pigeon-holes existed". Dr. Siddiqi discusses in his article other equally unsuccessful attempts to locate specific memory traces in the cortex. All these negative results are highly counterintuitive and puzzling, for it is difficult for us to understand how highly complex symbolic activities can be learned and retained in the absence of very particularised internal representations of these symbolic details. And if they are to be there, what is the alphabet that is used for building up and preserving these internal representations? Quite clearly, either we are asking the wrong sorts of questions, or there are fundamental gaps in our understanding of the processes and mechanisms that underlie remembering and recall.

As in the case of studies on aphasia, although we do not yet have the rudiments of a viable physiological theory, at the behavioural level a considerable amount of verifiable data has been accumulated concerning remembering and recall. A very readable account of these may be found in a paperback, *Memory*, by I. M. L. Hunter.

The one basic conclusion that emerges from all the psychological studies in this area is that recalling does not consist of a simple *duplication* of some past event. It is a highly *selective and constructive* activity. One must not confuse recalling with reciting — reciting something that has been rote-memorised. For example, reciting a poem or a *sloka*, a postal address or a telephone number. Rote-memorising is simply the formation of a chain of stimulus-response associations for the most part. "It is a habit of the vocal machinery, learned through repeated trials (rehearsals) according to the laws of habit formation". However, even in these cases two successive recitations by the same person are seldom exact copies of each other. Although the text may be faithfully reproduced in each case, there are likely to be significant variations in rendering, in intonation, rhythm, etc.

But recall of a past experience, a story we may have heard or read, or other factual details we may have been exposed to, is always a constructive activity. It is not like going to a cabinet and pulling out a stored item. The constructive nature of the activity may consist in the methodology of recall, or in the content of the recalled output, or in both, in general. As Hunter notes, even in such a simple act as recalling a person's name which is not readily available for recall one may go through complex procedures. "In attempting to achieve recall, we may be aware of some of the name's characteristics, for example, its rhythm or its length, or its first letter, or that it savours of some particular nationality, or that it is the same as that of some famous artist. . . ."

An interesting and simple experiment to try is this: take some fable, or a prose passage, or a news story, and ask a person to read it two or three times rapidly. Then, after an interval (during which time the person is kept occupied in some other task) ask the person to recall the passage as faithfully as possible. Get him to recall the piece again the next day, after several days, several weeks, months, and years, if possible. Now, compare the structures and contents of the series of recalled outputs. A variant of this experiment is the following: instead of asking the same person to recall repeatedly, give the output of the first person's recall to a second person, the output of the second person's to a third, and so on, to build up a series. Again make the same kind of comparisons of these outputs as in the first experiment.

Experiments in repeated recalls of these types were pioneered by the British psychologist F. C. Bartlett. He published in 1932 the results of his studies in a book called *Remembering* which has since then acquired the status of a classic in psychological literature. His findings have been replicated by others subsequently. Bartlett called these two types of experiments, the method of repeated reproduction, and the method of serial reproduction. In addition to using language specimens, he also tried these experiments using pictures and obtained analogous results (see Fig. 3, pp. 30-31).

Bartlett summarised his findings as follows. Literal recall hardly ever takes place. Almost always changes in the input material are introduced at recall. These may consist of both omissions and additions. The changes introduced are not arbitrary but occur in such a way that the material is conventionalised and rationalised. Both these transformations are carried out in conformity with the cognitive patterns common to the social milieu to which the individual belongs. The results of these transformations render the material easier to handle and to recall. In both kinds of experiments, these transformations reach a stable state after which recall takes place without further significant alterations.

To illustrate the kind of changes that take place, consider the following fragments taken from one of Bartlett's experiments in serial reproduction. The fragment is from the end of text used in the experiment whic called "The War of the Ghosts"

Original: When the Sun rose he down. Something black out of his mouth. His became contorted.

Serially reproduced outputs:

1. When the Sun rose he fell d And he gave a cry, and as he op his mouth a black thing rushed it.
2. When the Sun rose he suddenly faint, and when he would have he fell down, and a black rushed out of his mouth.
3. He felt no pain until sunrise the day, when, on trying to rise, a black thing flew out of his mou
4. He lived that night, and the next but at sunset his soul fled from his mouth.
5. He lived through the night and following day, but at sunset his fled black from his mouth.
6. He lived during the night and next day, but died at sunset, and soul passed out from his mouth.
7. Before the boat got clear of conflict the Indian died, and spirit fled.
8. Before he could be carried bac his boat, his spirit had left this w
9. His spirit left the world.
10. ("Nonsense" said one of the ot "you will not die.") But he did.

Bartlett comments: "The char come gradually, but the end is f shadowed from the beginning. F the 'something black' gains a k of force or vivacity of its own: rushed out'; then 'it flew o Then the activity receives expla tion, for the black thing becomes man's soul, and, by a common c ventional phrase, it is said to h 'passed out'. . . . Convent comes in again and the phrase ch ges to 'his spirit fled', and ev tually to the commonplace everyday: 'his spirit left the wor Then this phrase also goes the v of the others and there is nothing except the statement that the m died. . . . The total effect (of changes) is to make the whole incid ordinary and rational. But no one the subjects worked with the kn ledge of the thing he was doing."

The relevance of these findings what happens when stories circul or are handed down from generat to generation, should be obvious refer you to the book by Hunter interesting discussions on these poi

It would take too much space deal with all aspects of remember

recall. Clearly, recall is closely
ted to recognition. There is much
avioural data available on recogni-
. Recognition is easier to accom-
h than recall as anybody who
experience of answering exami-
ions based on open-ended ques-
s and multiple-choice questions
ws. Another closely related topic is
rgetting '. Are items once available
recall always available for recall?

Earlier I raised the issue of remem-
ing faces. Despite my remarks there
out ' photographic ' memory, it has
n found that certain persons, very
ng children especially, possess a
hly remarkable form of visual
mory which, for all practical pur-
es, behaves like a photographic
mory. This is called *eidetic*
agery and has been extensively
died although the physiological
sis for this is very little understood.
u should be able to find more
tails on all these topics in any good
ok on psychology.

But there is one last topic I must
something about before stopping
d this relates to methods of improv-
one's memory. It used to be
ought — and is, perhaps, still be-
ved by many — that memory can
strengthened by *exercising* it, just as
e strengthens one's muscles by
ercising them. William James quotes
amusing passage from a book
titled *How to Strengthen the Memory*
one Dr. H. C. Holbrook of New
rk. Says Dr. Holbrook: " I am now
ating a case of loss of memory in a
rson advanced in years. . . . The
ethod pursued is to spend two hours
ily, one in the morning and one in
e evening, in exercising this faculty.
. He is asked to recall every evening
the facts and experiences of the day,
d again in the morning. . . . Ten
mes from any public men are
dered to be committed to memory
ery week. A verse of poetry is to be
arned, also a verse from the Bible,
ily. He is asked to remember the
mber of the page in any book where
y interesting fact is recorded. . ."
mes comments: " I find it hard to
lieve that the memory of the poor
d gentleman is a bit the better for
l this torture except in respect of the
rticular facts wrought into it and
her matters connected therewith."

Is it, then, impossible to improve
's memory? What about all the
mmercial 'do-it-yourself' kits sold
the market for 'guaranteed'
mory improvement? About this
hat William James wrote almost a
undred years ago still remains valid.
e said, "All improvement of memory
nsists, then, in the improvement
one's *habitual methods of treating*
cts. Methods have been divided
into the mechanical, the judicious, and the ingenious. The mechanical methods consist in the intensification, prolongation and *repetition* of the impression to be remembered. . . . Judicious methods . . . are nothing but logical ways of conceiving them and working them into rational systems, classifying them, analysing into parts, etc, etc. All the sciences are such methods." Ingenious methods are the ones based on specially designed mnemonic codes of various degrees of complexity. All mnemonic codes are based on associative mediations. In this sense they are directly related to classical conditioning techniques. [See Dr. Siddiqi's article for details on conditioning.]

The account that I have given of memory and language behaviour in this article is necessarily sketchy and inadequate. But I hope even this brief outline brings out forcefully the vast gaps in our understanding of the brain mechanisms that support complex symbolic behaviour such as our use of language. As I have been emphasising repeatedly, we seem to lack an appropriate language even to formulate our problem in. Our everyday linguistic conventions lead us to talk about the operations of our mind as if they were the results of the " actions " of an autonomous agent residing inside us. Clearly this is a useless metaphor. On the other hand, in science, as in other spheres, we have to make use of analogies in the beginning stages if we want to make any headway at all. Our dilemma is that we do not yet have a serviceable analogy.

Professor J. Z. Young of the London University, in the Reith lectures that he gave over the BBC in 1950, made some very interesting observations about the use of analogy in the study of brain and behaviour at various periods in the history of the development of this subject. Descartes, who lived at a time when the design of clockwork automata had reached a high level of sophistication, argued that animals were automata of this kind. Later, when telephone exchanges were invented, it seemed natural to compare the brain to a complex switchboard. More recently, computer technology has provided its own specialised inventory of terms, such as software, buffers, subroutines, and so on. But, as I pointed out earlier, comparing our memory to a storage device, in the sense this is understood in computer architecture, raises more problems than it solves.

The basic problems we have to address ourselves to are, determining what kind of information is stored (" retained " is probably a more neutral term) and how this information is *represented* internally. It is quite clear that a good deal of our knowledge is skill-based. In such cases we can at least theoretically argue that the internal representation must be in terms of the action sequences (or complexes) that enable us to exercise these skills. Although I personally tend to believe that a good part of our memory is based on our action mechanisms, it is difficult to account for everything in these terms. For example, what mechanisms could we invoke to account for eidetic imagery?

One aspect of the physiological system I have not referred to at all is the part that underlies our affective and emotional states. It is well known that these states play a fundamental role in determining our behaviour — in determining what we perceive, how we perceive, what we learn, how we perform intellectually, and so on. The functioning of memory — remembering, recalling, forgetting, recognising — must clearly be decisively determined by this part of the physiological system. Although a large amount of behavioural data exists concerning these aspects, again, we do not have the rudiments of a coherent picture of how the total system functions.

Let me close by drawing attention to the fact that, although we know much about the mechanisms that give rise to the observed behaviour of the Sun and stars, our understanding of our own behaviour is pitiably fragmentary. To quote Professor Young: " The study of the brain is certainly one of the most challenging of all scientific problems. At present we spend much of our mathematical and physical genius on the study of the world around us. Why not apply more of it to ourselves and especially to our brains? "

A Senior Professor at the Tata Institute of Fundamental Research and Director of the National Centre for Software Development and Computing Techniques (at the TIFR), Prof. Narasimhan (51) did his MS in electrical engineering from the California Institute of Technology, Pasadena, USA, and both his MA and PhD in mathematics from the Indiana University, USA. A computer scientist, his research interests include visual data processing, programming language theory, models of language behaviour and application of systemtheoretic concepts and techniques to the study of behaviour and behavioural sciences. Fellow of the Indian Academy of Sciences and also the Indian National Science Academy, he was also awarded the Jawaharlal Nehru Fellowship for 1971–73.

MEMORY AND 'TRUTH DRUGS'

During World War II, the German Gestapo was said to have used some form of " truth drugs " to make captured resistance fighters confess or reveal secrets they otherwise wouldn't even under extreme torture (Remember Alistair McLean's *Guns of Navarone*?). The drug was believed to be scopolamine, one of the narcotic alkaloids (the others are hyoscyamine, atropine and polandrene) of plants like Mandrake root, nightshade, belladonna, henbane and Jimson weed — all belonging to the family *Solanaceae*. Incidentally, these plants have been known since ancient times for their 'awesome' powers to alter perceptions, ideas and emotions.

Psychiatrists sometimes use hypnotic drugs in narcoanalysis — to stimulate patients' talk. There are some forms of psychiatric disorders — Sigmund Freud was the first to call it 'repressing' — in which there is " an unconscious blocking of recall of certain experiences which have the potentiality of causing the person pain ". There is very scattered published literature on narcoanalysis. The best overview, perhaps, is contained in Lawrence Z. Freedman's article " Truth Drugs " in *Scientific American*, March 1960. (The term 'truth drugs' derives from the popular belief that they " chip away the conscious control of behaviour and lay bare the truth ".)

Freedman has cited the investigations of Humphrey Davy into the effects of nitrous oxide (laughing gas) at the close of the 18th century. Davy had persuaded Coleridge, Robert Southey and others like Roget (of the *Thesaurus* fame) to record their sensations on inhaling nitrous oxide. He himself wrote: " I gradually began to lose the perception of external things, and a vivid and intense recollection of some former experiences passed through my mind, so that I called out, 'What a concatenation of ideas!' "

Davy had noted that the physical and mental effects of the gas varied among individuals, their temperament and mood. Davy's observations went unnoticed. Years later, William James was to pick up the idea, though: "Our normal waking consciousness as we call it is but one special type of consciousness, whilst all about it, parted from it by the filmiest of screens, there are potential forms of consciousness entirely different. We may go through life without suspecting their existence; but apply the requisite stimulus, and at a touch they are there."

The first psychiatric use of such drugs came accidentally in 1916 at the University of Wisconsin where Arthur S. Loevenhart and colleagues were experimenting with respiratory stimulants on catatonic patients. One patient, for long rigid and mute, suddenly relaxed and opened his eyes after an injection of sodium cyanide; he even answered a few questions. Later, at the Massachusetts General Hospital, Erich Lindemann established that the drugs, most probably, removed certain psychic inhibitors and thus brought about verbal release. Modern studies have shown that the drugs affect the higher brain centres generally — those regions of the cerebral cortex that are usually thought to be of the most recent evolutionary development and are engaged in higher associative and behaviour-organising functions — the cause is a diminution in the brain-tissue metabolism brought about by the drug. Larger doses, in turn, depress the functions of the next lower centres. However, the action depends on the personality, tolerance level and environmental stimuli.

Early in the century, physicians had used scopolamine with morphine and chloroform to aid women in childbirth (to induce the 'twilight' state of sleep), and it was found that such women often volunteered very candid remarks. It was, however, the remarkable 1922 experiments of Dr. Robert House of Dallas in Texas involving the use of scopolamine in interrogating suspects in custody that brought this drug into the public eye. What was not so well publicised was that scopolamine had later been disqualified as a truth drug after the discovery of its several toxic side-effects. (Incidentally, scopolamine is more commonly known as hyoscine.)

Scopolamine's place has been taken over by sodium amytal and sodium pentothal. Sodium pentothal was used in narcoanalysis of emotional casualties during World War II and the Korean War. It must be mentioned here that though law courts do not admit evidence obtained by involuntary examination under drug, the chemicals are still being used in some places in pre-trial investigation.

Freedman has pointed out that the popular misconceptions about 'truth drugs' arise from the ignorance about what the drugs seek to elicit: " The psychiatrist is not interested in establishing the truth in any probative sense. In the development of psychological reality . . . the patient's account of his fantasies and delusions is as significant as his reliable recollection of past events. Drugs may be helpful to the extent that they provide a 'psychological analgesic', a relief from the inhibition of anxiety and guilt that blocks communication with the physician ".

And talking about fantasies, there is the remarkable work by Frederick C. Redlich and Leonard J. Ravity Jr. of the Yale University using sodium amytal: on the one hand, they found, strong-willed normal people could maintain a lie (like an invented self-defensive story) even under the drug; on the other hand, neurotics with strong unconscious self-punitive tendencies not only tended to confess more easily but also to substitute fantasy for the truth, confessing to offences never actually committed.

P. P.

Models of Memor

S. RAMANI

" The stream of thought flows on; bu of its segments fall into the bottomless ab oblivion. Of some, no memory survive instant of their passage. Of others, it is co to a few moments, hours or days. Others, leave vestiges which are indestructible, a means of which they may be recalled as l life endures. Can we explain these differen

— William James in *The Prin of Psychology*, V

The problem with words 'memory' is that they to a variety of com phenomena and, by gi them all a common and simple la they mislead you into looking f neat explanation that explains ev thing. However, recent investigat have, usually, taken into account diversity and complexity of mem related processes. We will now at a small set of questions that h been asked, and partly answered psychologists over the past decad two. They do not exhaust wha known, but they do give us some i of the variety of questions psychology asks and answers in increasingly satisfactory manner.

The questions

The simplest differentiation of mory is in terms of the time elem — short-term memory (STM) long-term memory (LTM) being v commonly used phrases in the lite ture. Visualise a cashier in a ba counting a wad of currency no The memory that helps him ke track of the steadily increasing cou need not be made of the sa " fabric " as the memory he has o friend whom he has not met in t last ten years.

Another dimension is that of senso origin. Do things seen and soun heard go through the same pathwa Once perceptions enter memory, they lose their sensory links, or do the memory of something heard dif in nature from the memory of som thing seen?

Then there are questions of pr cesses in memory. Let us take example. Do you know of anyone wh wears a tie regularly? How did yo arrive at this answer?

- Did the idea of tie-wearing instantly trigger off this person's name?
- Or did the names of a number of persons pass through a test procedure in your mind till one of them got selected?
- Are you aware of any person who was rejected by such a process as one who does not wear ties?
- Did you end up with two or three tie-wearers even though you wanted to name only one?
- Assuming that some search procedure did, in fact, go on in your mind, do you think that it could have gone on without your being aware of it?

If there are processes of the mind which operate on the " contents " of memory, what can we say about the nature of the " contents " themselves? Consider the following telegram:

APPEAR FOR INTERVIEW WITH OUR CONSULTANT AT OUR CENTRAL OFFICE IN NAGPUR NEXT FRIDAY

- What kind of structure will the data in this telegram fit into?
- Will the words of the telegram be remembered in sequence?
- Will the grammatical form be forgotten while the meaning gets captured by the long-term memory?
- Does any model of language predict the nature of success and failure experimental subjects will have in remembering various features of the telegraphic message, grammatical as well as semantic?

An interesting point about the questions raised here is that many of them could not have been asked a few decades earlier. The concepts necessary to frame and answer these questions — search process models, appropriate structures for representing information, coding and transformations of information from one form to another, pathways and buffers — were not available in an earlier age.

Some of these concepts can be examined now by discussing a few of the questions raised above; of course, we do not promise an exhaustive set of answers.

A pathway for certain visual impressions

It has been known for nearly a hundred years that visual information is gained in short bursts. You may not realise it, but your eyes are making many quick movements every second: they take in information only during brief pauses between these movements, called saccades. The pauses are called fixations and they provide the eye with a rapid series of still pictures. It is, therefore, understandable that psychologists have investigated in detail the perception of images in brief exposures.

Fig. 1 Tachistoscope used by George Sperling to investigate short-term memory. For 1/20 of a second, arrays of letters (as shown in Fig. 2) are shown; the subject later reports the letters he remembers

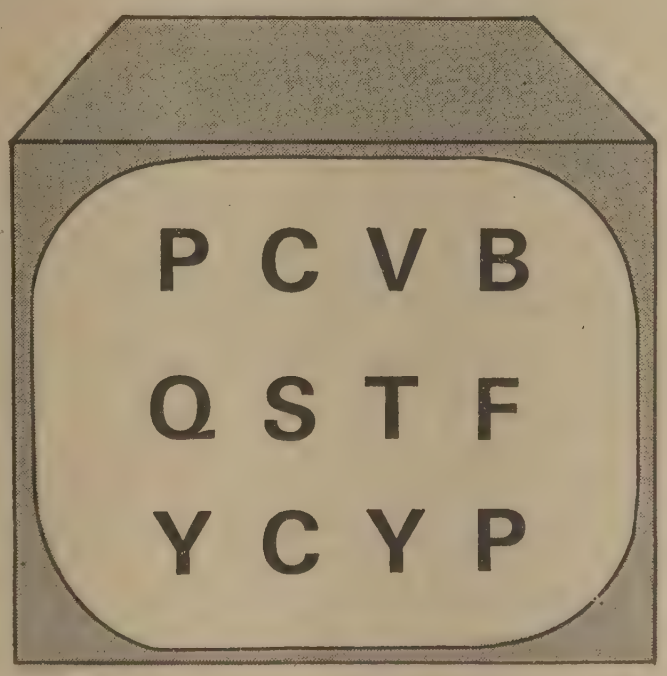


Fig. 2 Typical visual stimulus, projected for 1/20 of a second, preceded and followed by dark screen, to avoid interference from other images

A commonly used device is the tachistoscope which you can think of as a slide projector with a timed shutter of the type one finds in cameras (Fig. 1). Investigations in this area normally involve the presentation of a picture (Fig. 2) containing a number of letters for a very brief period to human subjects, who have to report the letters they see. The average number of letters correctly recalled varies from four to five. The duration of the flash which projects the image is usually in the range from one-hundredth of a second to half a second.

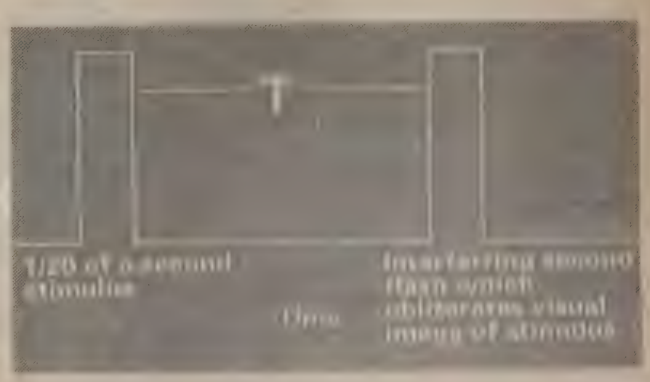
Initial experiments of this type were conducted 80 or 90 years ago. Recent work in this area was pioneered by George Sperling, who threw considerable light on the way information is processed in this task. Sperling started with a couple of important observations:

- Subjects reported that they noticed the presence of many letters even though they could recall only four or five correctly.
- Subjects could report (four to five) letters correctly even after several seconds of waiting following the stimulus presentation.

The question now was about the presence of a visual information store (VIS), or visual memory, which by itself could explain the outcome of these experiments (Fig. 4). Sperling repeated, with certain refinements, the experiments originally carried out by Baxt (around 1871), in Helmholtz's laboratory, to investigate this model. These experiments involve a second stimulus presented after a controlled time (T in Fig. 3) following the original stimulus. As long as T exceeds 0·1 second, the second stimulus does not affect the number of letters recalled from the first stimulus.

If the model shown in Fig. 4 is to be believed, there is only one information store. The second flash, following the stimulus after a delay of 0·1 second, would disturb the contents of this store. How does the subject hold on to the stimulus for several seconds? Clearly, one can rule out this model on this ground. There is a need for a second information store in which information on stimulus letters can be held without being destroyed by the second flash.

Fig. 3 Time sequence of events for investigating the nature of visual memory. As long as T exceeds 0·1 second, the subject's recall of letters in the original stimulus is not affected by the second flash



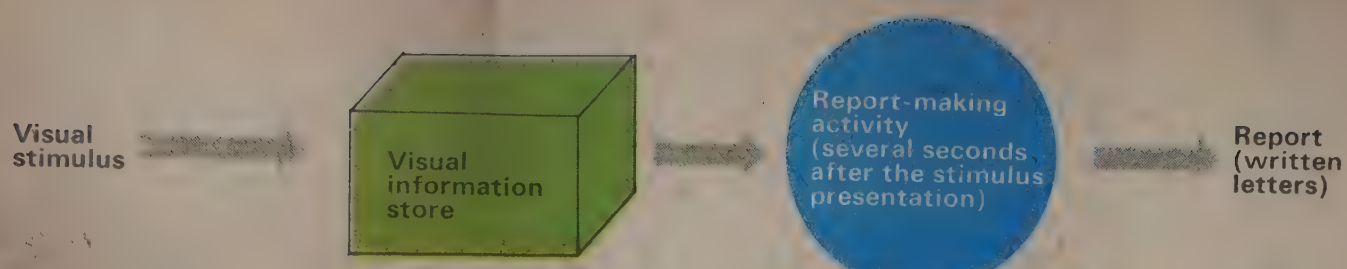


Fig. 4 Model based only on visual memory

There is good evidence to believe that the second store involved in the behaviour being discussed is an auditory information store (AIS). Even though the recalled letters are reported in writing, the subjects make mistakes which betray the involvement of an auditory store. Seeing D and reporting T or seeing 2 and reporting T are examples of such mistakes. If they see 2 and report Z, one would ascribe this to confusion between visually similar symbols, but T and D or T and 2 are alike only in terms of sound.

The AIS would, of course, explain the ability of a subject to give a report several seconds after the stimulus, even after the contents of the VIS have been disturbed by a second visual stimulus.

Information given in the spoken form can be remembered for several seconds. The fact that subjects who have to remember a list of symbols frequently speak out its contents (silently or aloud) to themselves is well known. This is called rehearsal. Fig. 5 shows how rehearsal can feed back to an AIS its own contents. Suppose contents of an AIS decay over a few seconds when left alone. Rehearsal can be used to increase the time over which the memory is kept alive by this AIS.

In experiments of the type Sperling conducted, one can try to disturb the subject's memory by playing a recorded voice which calls out a series of digits not connected with the symbols shown visually. Since the subject's task is to remember what he has seen and to report it, the irrelevant speech signal acts as a disturbing agent. It causes a small but definite decrease in the number of symbols the subject can remember (and report) out of those he has seen. Further, the disturbing speech signal often forces subjects to mumble to themselves (use rehearsal audible to an observer) what they have to remember. In this manner, they seem to be counteracting the effect of the disturbing sound. All this constitutes evidence in favour of the idea that an AIS is involved in remembering and reporting what is seen.

Speed mismatch: visual scanning and auditory rehearsal

The model of Fig. 5 is surely an improvement over the model of Fig. 4. But, it has its own weaknesses. By visual interference techniques (Fig. 3), it has been shown that the information in the VIS is moved out at the rate of one letter (or symbol) every one-hundredth of a second. But the AIS does not seem to accept input any faster than one letter for every one-sixth of a second.

Consider the model shown in Fig. 5 in the light of these transfer speeds. What does this model predict regarding the number of signals that can be remembered from a momentary visual presentation? Clearly, the number of symbols reported will be:

$$\left[\frac{\text{available transfer time (for moving from VIS to AIS) in seconds}}{6}\right]$$

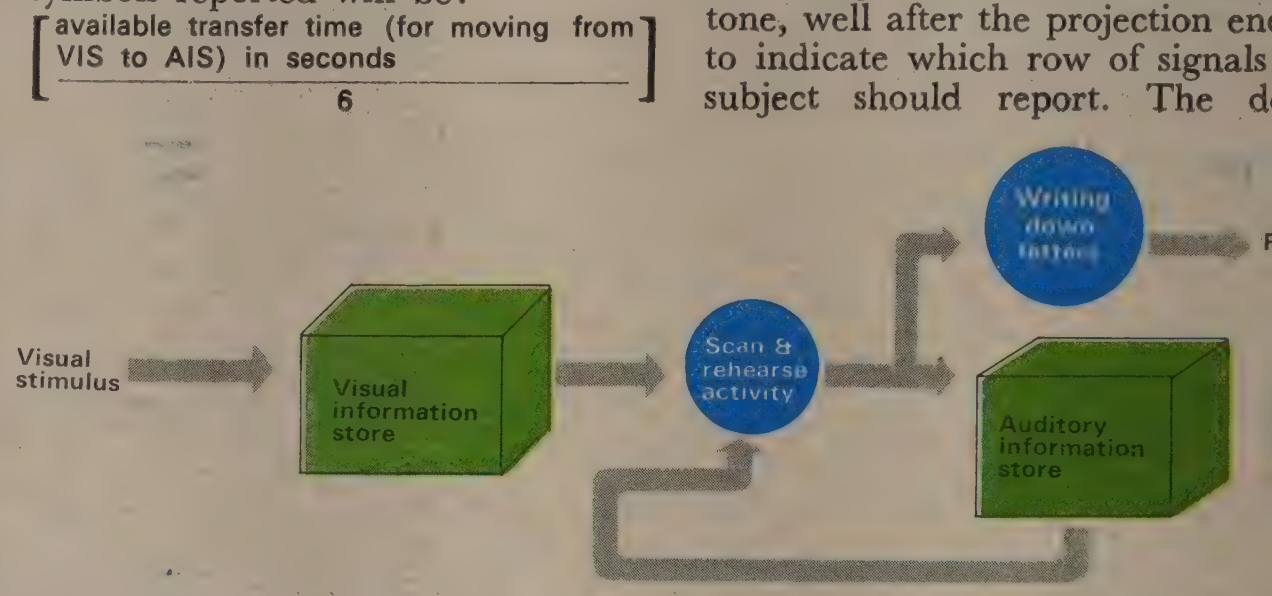


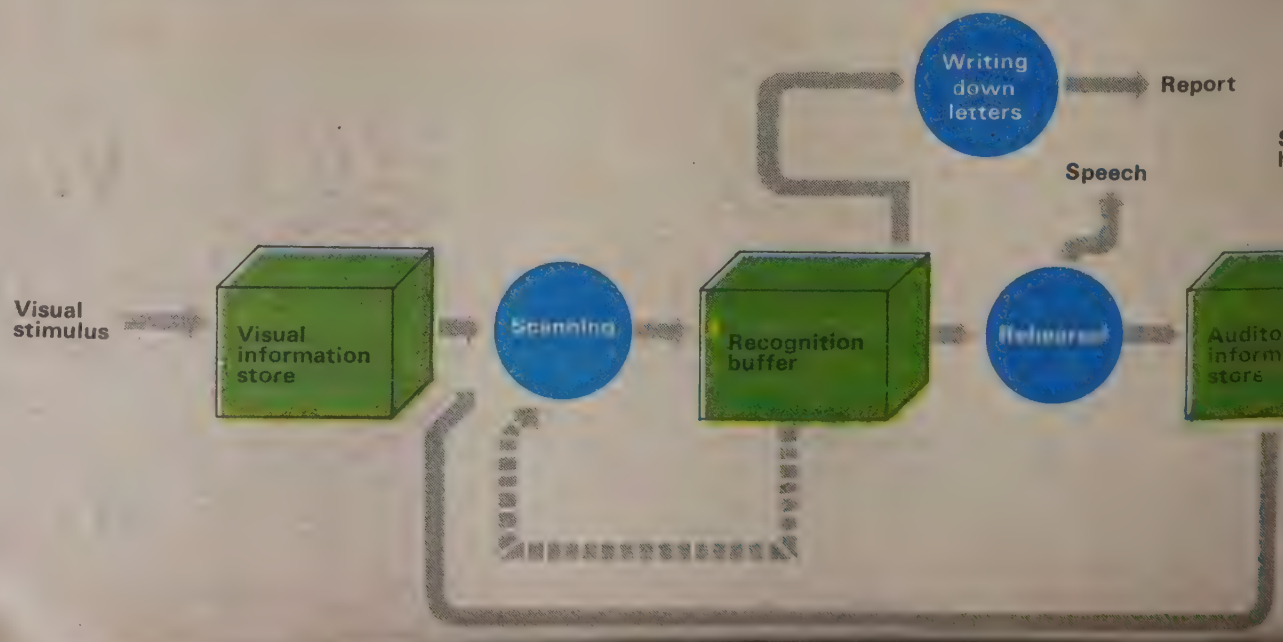
Fig. 5 Model involving an 'auditory information store'

This is because the AIS can accept only around six symbols per second.

This prediction turns out to be wrong. Sperling showed that even when an image was left undisturbed only for 0·1 second in the VIS, the subject was able to report 4 or 5 symbols from those seen.

Sperling chose the model shown in Fig. 6 to explain this ability. This model contains a third information store called the recognition buffer to accept information at a rapid rate

Fig. 6 Model incorporating three stores

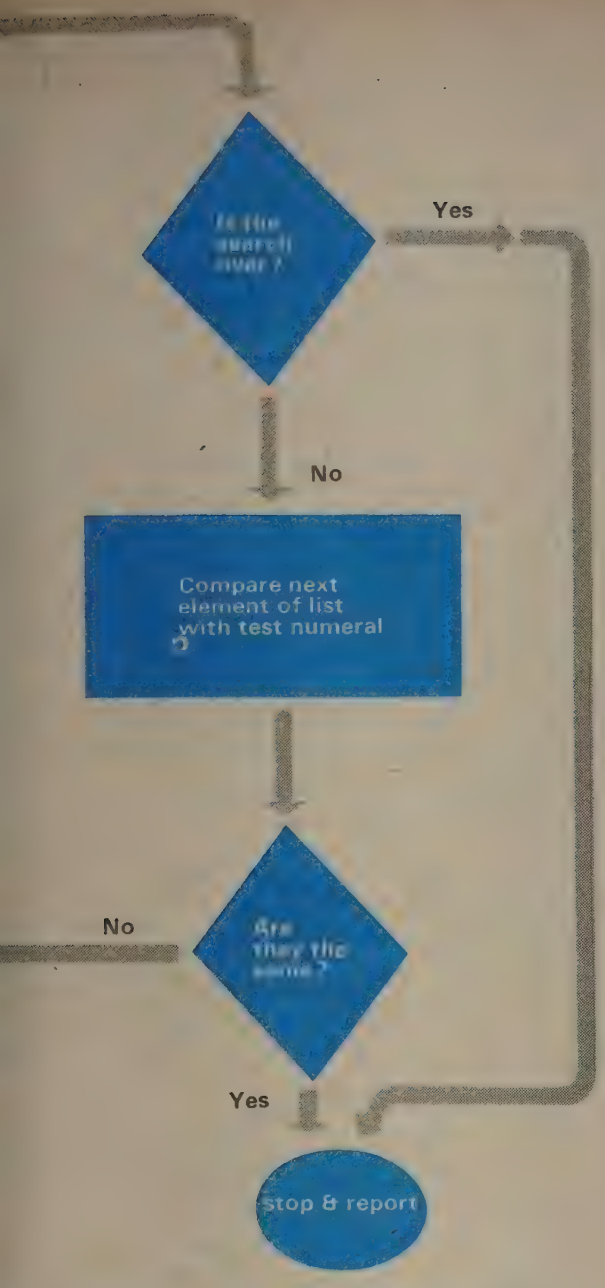


from the VIS and to keep it while AIS accepts it at its own rate.

Capacity of the VIS

One of the interesting outcome Sperling's work was an estimate of capacity of the VIS, which tur out to be larger than expected. know that the subject in his exp ments generally reported only 4 symbols. What was the main ca of the limit? Was it due to the lim capacity of the VIS, or limited ca city of the AIS, or was it due to speed with which information in VIS can be processed before its c tents decayed or were disturb Sperling showed that the capa of the VIS was not the limit. In of his experiments, he projected th rows of symbols (Fig. 2). The pro tion lasted 1/20th of a seco Following this, he would sound tone, well after the projection end to indicate which row of signals subject should report. The de between the projection and the to was varied from 0·1 second to second in different experiments. T subject was to report the top, mid or bottom row, depending upon high-pitched, medium, or low-pitch tone being heard.

It turned out that the subject cou report the chosen row without di culty, indicating that the VIS is lar enough to keep all the symb (around 12) for a fraction of a secon unless the VIS is disturbed by ne input. Similarly, one can show th the AIS itself has a capacity larg



g. 7 Serial search of short-term memory

an the number of symbols the sub-
ct reports in Sperling's experiments
or 5). This leads to the belief that
e limit to the number of symbols
ported is due to the low processing
te beyond the VIS. Information
ndling beyond the VIS takes a
finite time for each symbol being
ported. While this processing is
ing on, the information in the VIS
decaying. The rate of processing
such that only 4 or 5 symbols can
'grabbed' by later stages before
ey decay. That the capacity of the
IS is large is shown by the fact that
many as twelve symbols can be
ored in it, and any four of them
grabbed' on the receipt of a tone
gnal which arrives after the pro-
cted image has disappeared.

Sperling's experiments probed the
ature of stores or buffers that are
volved in remembering visually
resented information. An interesting
ct is that in models of the type
nsidered by Sperling (Figs. 4 to 6),
lmost equal importance is given to
rocesses, the circles, as to the stores,
e cubes. It is possible to identify
ecific processes and to probe into
em in depth. A good example of an
vestigation of this type involves a
arch process.

earching short-term memory

A set of experiments reported by
aul Sternberg deal in detail with the
ature of search that is involved in
e item recognition task.

It is essential at this stage that you read the box "The numeral recognition task" (right). You must take the test given in that box, and then read the description of Sternberg's varied-set procedure for this task.

By offering payments to volunteers for correct and quick responses and penalising errors, Sternberg got his subjects in the numeral recognition task to give correct answers 98 or 99 per cent of the time. He then set out to investigate the nature of the recognition process that enables subjects to identify a test numeral as one in the memorised list or one that is absent. He recorded the reaction time RT: the time between presentation of the test numeral and the response, lever-pressing. He found out how RT changed as one increased the difficulty of the task by increasing the length of the list to be memorised. He also examined if RT was different for positive responses (test numeral is in the memorised list) and for negative responses (not in the memorised list). Several other factors were also studied. Suppose the same list is used in one trial after another, so that it becomes more familiar than a list learnt for a specific trial. Does the RT change? (Briefly, the answer is, no, it does not). Suppose we use photographs of human faces instead of numerals. Does this change the experimental results significantly? (No, it does not.)

Models for the search process

Since the Sternberg experiments involved the study of many different factors, it is necessary to look into his results step by step: take the effect of a specific factor, take specific hypotheses, and then look at experiments relevant to these; examine the possible alternative models and see which ones are supported by the experiments.

One possibility is that comparison of the test numeral could occur simultaneously ('parallel search') with all the remembered numerals. If this is the case, reaction time (RT) will be the same irrespective of the number of numerals in the memorised list.

Alternately, comparison could be a 'serial search', as in Fig. 7. Such a serial search predicts that RT will increase with the length of the list, since a set of operations have to be repeated for each list element. Experiments showed such an increase:

No. of elements	RT (sec) (approx)
1	0·44
2	0·48
3	0·52
4	0·56
5	0·60
6	0·64

THE NUMERAL RECOGNITION TASK

(Take a pencil and paper before you start.)

You will be given a list of five numbers. Memorise it :

7
2
4
8
6

Have you read the list carefully?

You will now be given a set of numerals. Read each numeral, one at a time, and place a √ mark next to it if it is in this list memorised. Now, to get the test numerals, turn the page.

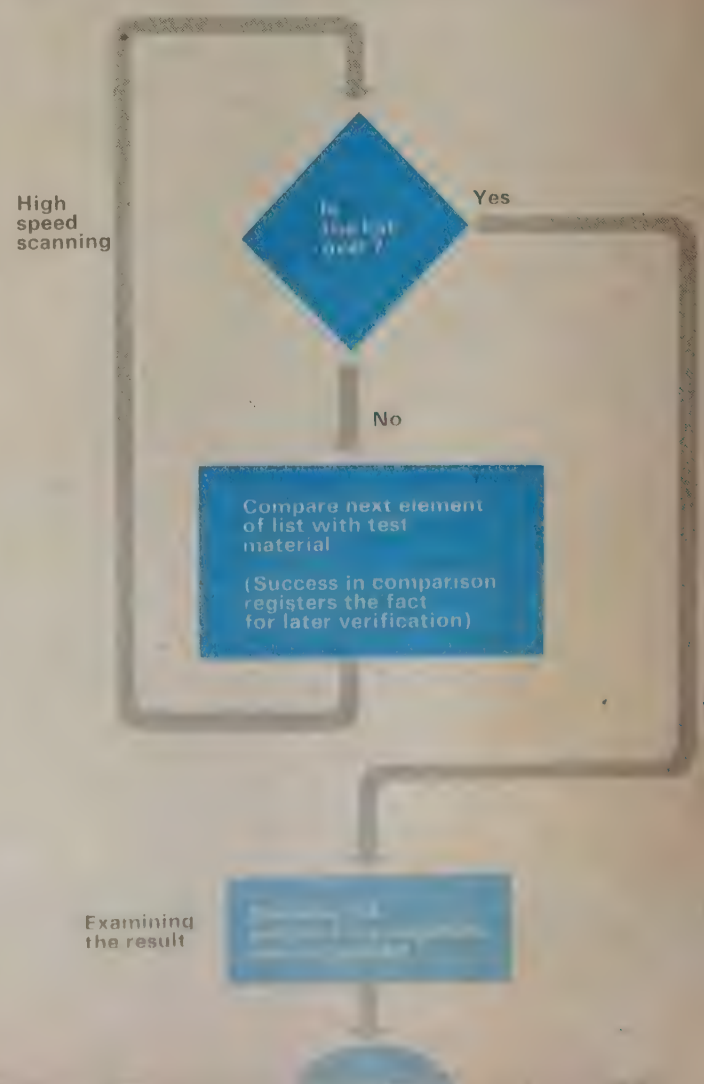
There seems to be a minimum RT of about 0·4 second which can be attributed to activities carried out only once, such as result-reporting.

Is the serial model satisfactory?

To investigate the model further, we can draw other verifiable inferences from it. For instance, will it take longer to recognise that the test numeral is in the list, or, will it take longer to say it is not there? Obtaining a successful match obviously terminates the process in Fig. 7, but failure to get a match can be reported only after scanning the completed list. So one would expect that a recognition will be reported after a shorter RT than a failure to recognise.

Secondly, what about the position of a recognised numeral in the list? Shouldn't one be quicker to recognise a numeral at the top of the list than one that occurs later on? Hence the

Fig. 8 The exhaustive serial search model



THE NUMERAL RECOGNITION TEST

Read the following, one at a time, marking each numeral with a √ if it is in the list memorised:

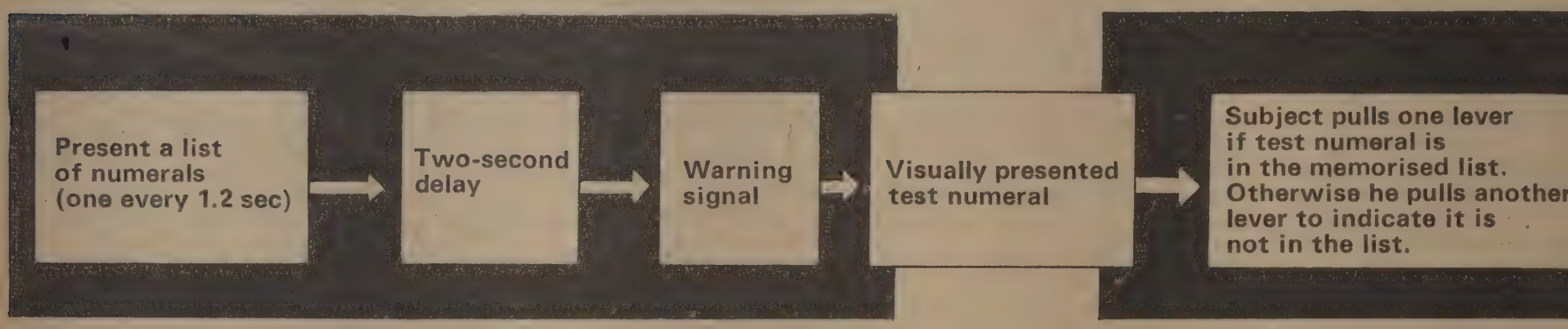
5
4
3
9
2

AIS is often provided by indications that the subject 'rehearses', sometimes to the accompaniment of audible mumblings, and sometimes without audible sounds (sub-vocally). Experiments indicate that even sub-vocal rehearsals cannot be very fast, certainly not fast enough to examine each element of a list in 1/25th of a second, as demanded by the Sternberg models. So, he probed the

If abstract representations are u in comparisons, we should expect RT will increase by a fixed amo irrespective of the length of memorised list. On the other hand non-abstract representations are us RT will increase in a different man when visually good inputs are repla by visually degraded ones. The crease will be proportional to length of the memorised list. Ste

Sternberg's varied-set procedure for the numeral recognition task

This is very similar to the test you have taken just now (see above).



The list of numerals used is changed before it can become part of the long-term memery.

model of Fig. 7 predicts a smaller RT for numerals earlier in the list.

Experiments failed to support these two predictions. Sternberg demonstrated convincingly that RT was the same for reports of recognition as for reports of failure in finding the given numeral in the list. He also showed that RT was reasonably independent of the position of the recognised numeral on the list. On the basis of these findings, he chose the exhaustive search model of Fig. 8. In this model, the search for recognition is a fast operation (scanning) which ends only when every element of the list has been compared with the test numeral. A match is recorded for later examination, but it does not stop the scanning. Sternberg theorised that examining the "match register" to make a decision (say, to continue the search, or to terminate it) was a time-consuming operation. Hence it is more economical to do it only once.

The scanning process is a fast operation: Sternberg's estimates indicate 25 comparisons per second are common.

The nature of items in the short-term memory

You would remember that George Sperling found that an STM in his model was an auditory information store (AIS). Even when the stimuli were visually presented, information on them was stored in the AIS. Now, we can ask if the STM involved in performing Sternberg's numeral recognition task is also an AIS. You will remember that major support for the involvement of an AIS is often provided by indications that the subject 'rehearses', sometimes to the accompaniment of audible mumblings, and sometimes without audible sounds (sub-vocally). Experiments indicate that even sub-vocal rehearsals cannot be very fast, certainly not fast enough to examine each element of a list in 1/25th of a second, as demanded by the Sternberg models. So, he probed the nature of the STM involved. For this purpose, he used 'visually degraded' test numerals (Fig. 9) in the place of the clean or 'intact' numerals used earlier. The nature of change in RT due to the use of these degraded stimuli gives valuable evidence regarding the properties of the STM involved.

There are two possibilities:

(*i*) The memorised elements and the test numeral are represented in memory in an abstract form. Visual quality of presentations (intact or degraded) should not make a difference to the abstract form in which information is stored in the memory. Of course, there may be a fixed delay introduced in converting a test numeral which is visually degraded into the abstract form.

(*ii*) The representation of numerals in the memory is changed by visual quality of the presentation. In this case, the time taken for every comparison will change as a result of visual degradation of the test stimulus.

Let us consider the RT measured in experiments involving intact stimulus numerals. To this we can add predictions based on the two possibilities discussed above.

Length of memorised list	RT	RT1	RT2
1	·44	D+·44	·44+k
2	·48	D+·48	·48+2k
3	·52	D+·52	·52+3k
4	·56	D+·56	·56+4k
5	·60	D+·60	·60+5k
6	·64	D+·64	·64+6k

RT1 is the prediction made according to the possibility (*i*) above for degraded stimuli. RT2 is the prediction as per possibility (*ii*) above.

berg's experiments verified the p diction marked RT2 in the ta above.

A part of the picture that emer from Sternberg's work on the nume recognition task can be described follows:

(*i*) a short-term memory is involv in which information is not present a pure or abstract form;

(*ii*) comparisons can be made w the contents of this STM at rates high as 25 per second;

(*iii*) the fast comparison operati always runs to the end of the list, ev when an element of the list matc the item being searched for;

(*iv*) lists of visually 'degrade items are stored in such a mann that comparisons of these degrad items with a given item take a long time than comparisons of 'intac items.

Sperling's and Sternberg's expe ments indicate the kind of questio that are profitable to ask about t STM and the type of experimen that give us answers to these questio There are, of course, many oth questions about the STM that w cannot deal with here in a few page But a couple of points are wor mentioning.

One is the question of our bei conscious of different parts of o memory and their activities. Wha ever is in the VIS gets lost and never noticed unless it is taken up f further processing. That our memo for a visually degraded numeral tak more time in a comparison than t memory of an intact numeral w

never known to most of us. It becomes fairly clear from all this that we are unconscious of information processing going on in parts of our mind. Is this a disturbing idea? Is it more disturbing than the fact that one is unaware of the existence of, say, his liver and its functions till he is taught about it?

The computer analogy

Another important point is the nature of limitations of the STM and their significance in human behaviour. Long-term human memory has a large capacity and searching for information in it possibly involves highly parallel operations. In contrast, the STM has a very limited capacity. In the middle of a problem-solving task, you are seriously limited by the capacity and the nature of the STM. Getting information into it and keeping necessary information from being displaced from it involve paying a price. The nature of mental activity we can carry out at reasonable speeds is very much constrained by these restrictions. Sternberg's finding that scanning in the STM is normally exhaustive (instead of being a self-terminating one) is a very important pointer in this direction.

We must compare the division of human memory into LTM and STM with the division of the information store in computers into a main memory and a set of registers. Most computers can store half a dozen or a dozen items of information in the registers and 1,00,000 items in the main memory. Registers provide an expensive short-term memory which speeds up work, but it has to be small in capacity to keep prices down. It is common for computer programs to use pointers to chunks of information in the main memory. A pointer is only one item of information, but it provides a link to a set of connected information items in a large memory. By using such pointers or 'associations', computer programs smoothly move in relevant information chunks to the high-speed registers when needed.

Another interesting fact is that, most computers operate in a highly serial fashion as far as computing is concerned. The set of registers deal only with one problem at an instant and the computer is performing only one computation at any given instant even though users often get the feeling that a computer is doing many things simultaneously.

Neither the use of a small capacity STM nor the highly serial operation are necessary properties of every conceivable computer. One could not have predicted from a knowledge of

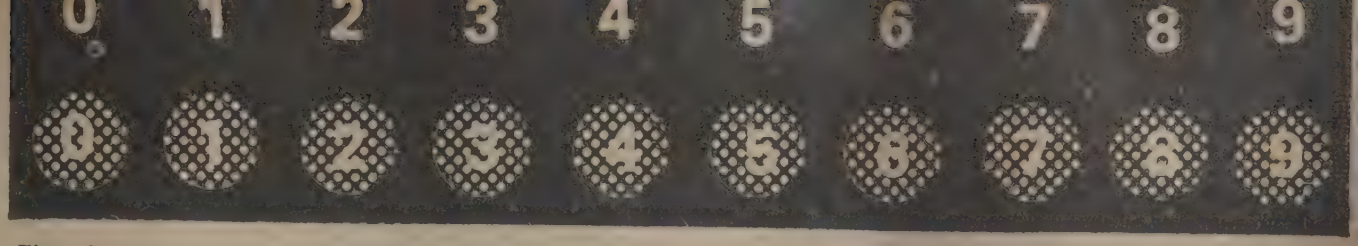


Fig. 9 Intact and degraded visual stimuli

the principles of computer design that the human mind should necessarily be limited in the capacity of the STM and in the number of operations it could be doing simultaneously. On the other hand, it is turning out to be the case that the human STM is quite small in capacity. Further, many of the activities involving the human STM are serial computations.

Why is this so? What can we say about these from reference to the computer analogy? There are advantages in having a single computation in progress in a computer involving the short-term memory. Any machine based on such a design would be much simpler than one which allows multiple computations to occur truly simultaneously.

Similarly, a computer design which involves a small-capacity high-speed store (naturally expensive) and a large-capacity low-speed store is a good design. We can surmise that this principle holds even in the case of the electrochemical machine that is so important to us. Fast access memory being more 'expensive' in biological terms could explain the use of a two-level memory system. A small fast memory holds items immediately relevant to an on-going process. Material required for further work would be brought in from the larger, slower store whenever needed.

While analogies should not be confused with the real thing, we should not also forget their utility in suggesting possibilities and identifying profitable lines of investigation.

Association: the mind's glue

Do you now recall the urgent message, mentioned earlier, which invited some one to meet someone else in connection with a job? It will be useful now to take a minute to think about it and write it down as clearly as you can recall it. You can then compare it with the original. This small experiment on your own memory would give you information useful in answering a number of questions that are going to be raised in the following pages.

There is no denying that information elements such as what the telegraphic message told you to do, where, when and for what purpose, were in some sense associated together to form a complex idea in your memory. Given one of the elements, say, 'interview', the mind is usually able to access the associated details. But theories which attempt to explain memory in terms of associations run into serious difficulties at an early stage. A classic example is the behaviourist attempts at explaining memory as nothing more than associations between stimuli and responses. Watson wrote: "By 'memory' then, we mean nothing except the fact that when we meet a stimulus again after an absence, we do the old habitual thing (say the old words and show the old visceral-emotional-behaviour) that we learned to do when we were in the presence of that stimulus in the first place."

Did you recall the urgent message which invited some one to meet some one else in connection with getting a job? Now let us examine the results of the simple recall experiment you have performed on your memory. Compare the original telegraphic message with the question which made you recall it. Well, there are not many words common to the question and the message. So, if words are the stimuli Watson refers to, one cannot explain how this question evokes recall of the telegram. On the other hand, assume that associations occur between ideas, not words. One need not rule out associations of words, but grant that it is the association of ideas that is the more interesting type. The ideas of what to do, where, when and for what purpose could then be visualised to be in association. Making a theory of associations of such a type is itself a monumental task, one which has engaged the attention of philosophers and psychologists since the days of the Greeks.

Since such theories deal with associations between ideas, their supporters have to explain how the mind goes from words and sentences to ideas. Since ideas are not observable, one has to theorise about what they are and how they are obtained from what one hears and sees. Are there simple ideas and complex ones? Are complex ideas built up by associating simple ideas together, clearly indicating how each one is connected with another? In other words, are complex ideas structures built with simpler ideas? If that is so, does grammar play a role in determining the structure of association in a complex idea? Do the sentences we hear and read undergo a grammatical analysis to have their parts (such as verb phrases, noun phrases, etc) identified to enable meaning to be assigned to them?

[See the article by Prof. Narasimhan (pp. 28–33); language behaviour and long-term memory have to be studied together. It is practically impossible to talk about one without talking about the other.] Or is the process of 'decoding' the meaning of a sentence an integrated analysis in which all clues, grammatical or otherwise, are exploited equally? The influential linguistic theorist Noam Chomsky had suggested that grammatical analysis alone should assign deep structures to sentences which could then be subjected to a semantic interpretation to assign a meaning to the sentence.

The nature of meaning

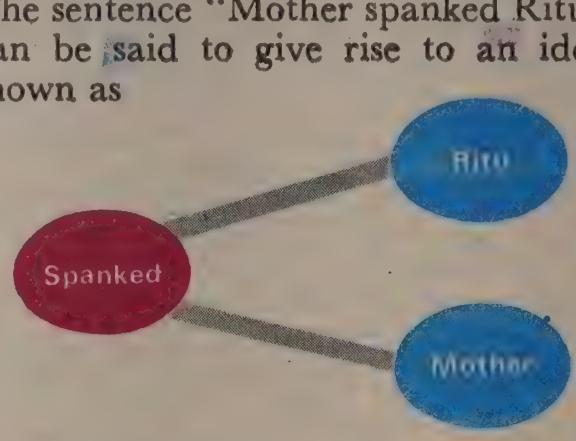
There is a general principle that all theories in this area have to honour. Postulated entities such as 'ideas' or 'meaning' should not be undefined or be loosely defined constructs. If that were to be the case, it will be useless to say that sentences are dealt with in terms of the ideas inherent in them. We would then have to construct another theory of what ideas are and how they are analysed, remembered, and so on.

An ideal solution would be to create a 'mechanistic' theory of ideas. For example, one could try to invent operations that can be carried out by a machine on the words of a given sentence which would result in a diagram or a set of 'equivalent sentences' embodying the ideas inherent in the given sentence. As long as 'the basic ideas' and the nature of allowed associations we postulate are mechanistic in the sense that they can be stored and be operated upon in a machine, we would be honest. Our theories could be subjected to a powerful test: can you get a machine to operate according to the principles of your theory, and simulate people's behaviour in answering questions based on the recall of information given earlier?

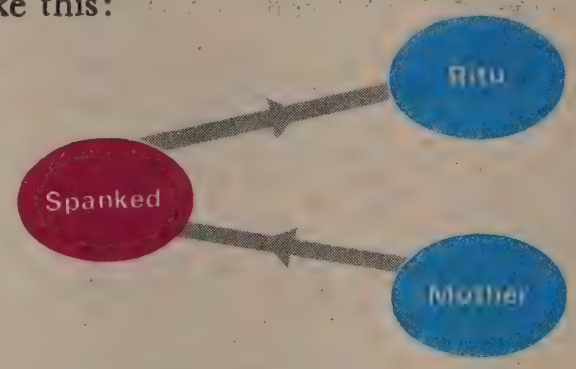
The standard practice is to program computers to handle information, analysing, storing and retrieving it as prescribed by a given theory; this gives valuable insight into the deficiencies of a given theory.

These attempts in simulation reached a notable degree of success with the experiments of Quillian whose work, reported in his PhD thesis and in later papers, have influenced associationist psychology considerably.

The value of simulation is that it forces one to work out a theory in detail. Consider, for instance, the suggestion that ideas can be thought of as nodes in a complex network which can be represented pictorially. Nodes which have an association between them are joined by a line. The sentence "Mother spanked Ritu" can be said to give rise to an idea shown as



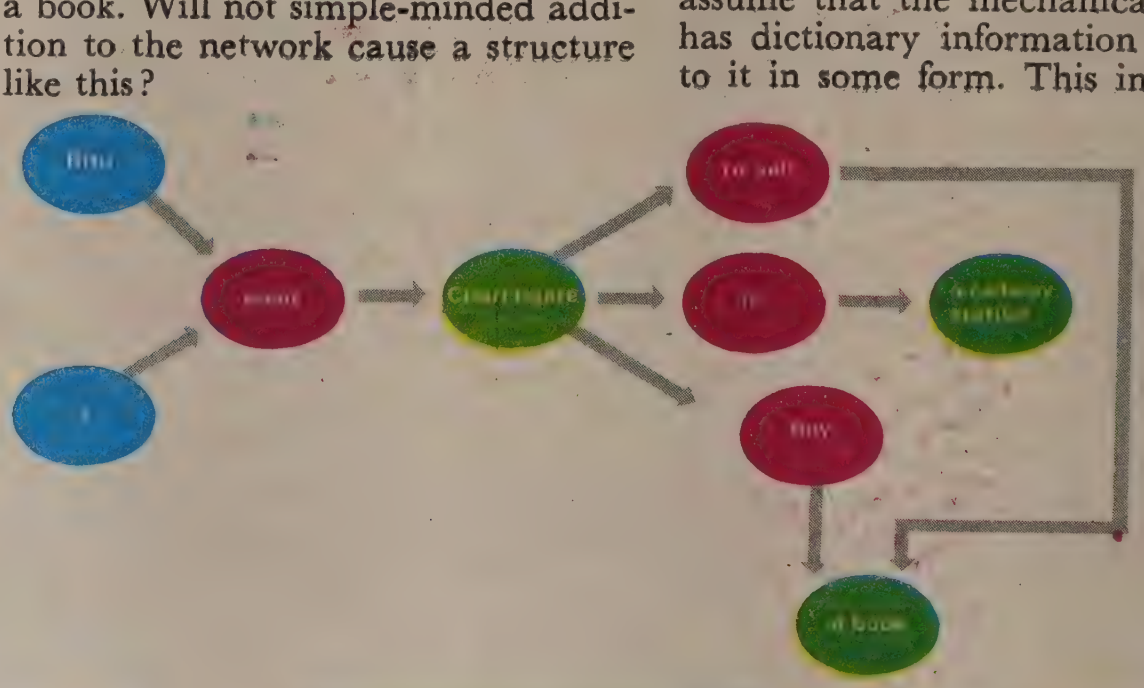
So, when someone asks what mother did, we can find the associative link from mother to "spanked" and answer it. This elementary proposal runs immediately into a problem. If the diagram is given to someone who interprets it mechanically, the question "who spanked who"? causes difficulties. Did mother spank Ritu or vice versa? So, clearly we need to add directional arrows to our diagram, like this:



Other questions arise very soon, as we go further in this direction. Consider the sentence:

"I went to Churchgate to buy a book."

Add to this the information that Churchgate is a railway station and that Ritu went to Churchgate to sell a book. Will not simple-minded addition to the network cause a structure like this?



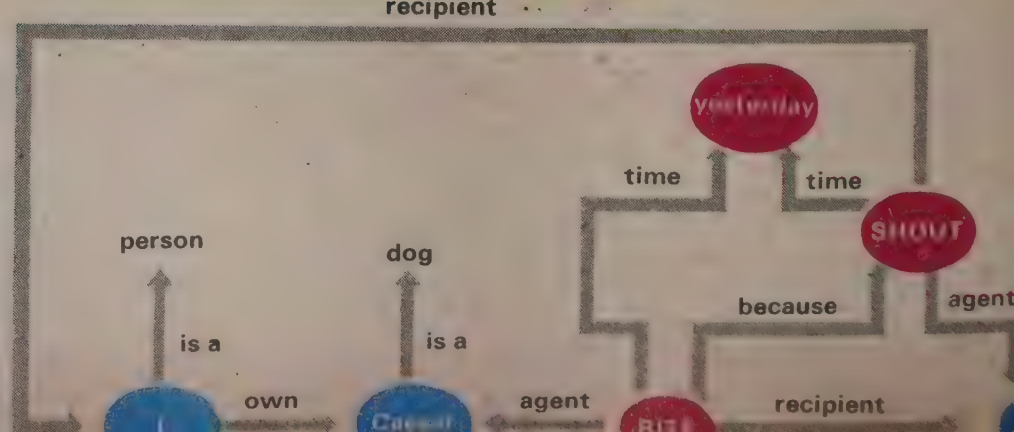


Fig. 10 Network of associations capturing the content of the sentence "My dog Caesar bit you yesterday because you shouted at me" (adapted from Lindsay & Norman)

Can a 'mechanical' search of t network find out "what you did Could it not say "I went to Churc gate to sell a book and Ritu went Churchgate to buy a book"? Furth a mechanical search could sa "Churchgate bought a book", whi is wrong. Even you may not ha bought a book yourself, you only we to Churchgate to buy it. Furthe was it the same book that Ritu we to sell that you went to buy?

Neo-associationism

Quillian's work computer simulation of his associ tionist theory has stimulated work this field by psychologists and com puter scientists. Some agreemer seems to be nearing in the matter the role that grammar plays in th decoding of sentences and in th creation of structures that captur their meaning. Quillian had taken daring step when he downgraded th role of grammatical analysis in com prehension in his model. A host others have now followed in tha direction, both in theory and i experimentation. The current tren places considerable importance on th use of a wealth of information in th comprehension process.

An example, rather popular wit linguists, will illustrate the point bein made here. Consider the sentences:

The pen is in the box (S1)

The box is in the pen (S2)

and consider their possibl 'mechanical' analysis, for obtainin the information they carry. Further assume that the mechanical analyse has dictionary information availabl to it in some form. This informatio

gives definitions for the words " pen " and " box ":

Box: A container or case of wood, metal, etc.

Pen: 1. A writing instrument. 2. A small enclosure (as in baby's play pen).

Using a common notation to distinguish between the two senses of the word "pen", we can say that pen 1 is the writing instrument and pen 2 is the enclosure.

When you read the sentences S1 and S2, it becomes clear that the pen in S1 is really pen1 while in S2 it is pen2. How did you analyse S1 and S2 to obtain this distinction? One possibility is that you used the information that the pen is a rather small writing instrument and that play pens (and pig pens, for that matter) are rather large to fit into boxes. Another possibility is that such ' world information ' is not used in comprehension but some dictionary definition of words in terms of a set of well chosen categories will be sufficient to enable the assignment of interpretations to (S1) and (S2). The consensus now is clearly in favour of the use of ' world information '.

The stuff that memories are made of

There are a number of associationist theories, worked out in some detail, that are free from faults of the kind mentioned earlier. The suggested reading list (p. 41) mentions several relevant references. Fig. 10 gives an idea of the type of associative structures such theories propose. An important effect of working out details has been that these theories are now making verifiable predictions.

Anderson and Bower, for instance, predict structures such as the one shown in Fig. 11. How different are these structures from the ones suggested by various types of grammars, for example, the one shown in Fig. 12? Anderson and Bower answered the question by predicting on the basis of their model how people will behave while recalling propositions after having read many of them. Read the following sentences and decide if the information they contain agrees with that of the proposition shown in the Figs. 11 and 12 (without looking at the figures again). Dashes indicate parts of the proposition that are irrelevant to this test.

1. The dentist————the———— on Wednesday.

2. ————kicked the————on Tuesday.

Anderson and Bower's predictions dealt with the question *what is more likely to be forgotten* (associations that are several links long) and *what is more likely to be remembered* (associations between nodes close to each other on the structure proposed). They obtained experimental results to compare with the predictions. Dosher used a more sophisticated technique, controlling the time available to the subject to make a decision, and investigating the percentage of correct yes/no decisions made. These experiments broadly support the type of structures shown in Fig. 11 in comparison to others such as the one shown in Fig. 12. The techniques involved are quite complicated and it is worth noting that the issue is not yet considered closed. The important point is that, proposals for associative structures are being taken seriously and are subjected to experimental verification.

Structure of propositions: experimental verification

The Anderson and Bower model suggests that the *subject* is more closely associated to the *verb* and *object* than it is to the *location* or *time*. It similarly predicts that the *verb* is closer to the *subject* than it is to location or time.

Dosher asked subjects to study 14 sentences containing the constituents: AGENT(A) VERB(V) OBJECT(O) LOCATION(L) TIME(T). Then she presented them pairs of constituents such as *subject-location*, indicating the other constituents by dashes. For example, memory for a sentence read earlier can be tested by asking you to decide if the following partial sentence agrees with the one you have studied:

The ———— kicked the ———— in the desert on ————. Dosher calls this a *verb-location* probe.

The ' strength ' of the association (in this case between the *verb* and *location*) is estimated by a performance index d_t (basically an estimate of a signal to noise ratio, obtained by a complicated method). Dosher tested a variety of probes and the table below provides some information that her experiments have brought out. A high d_t in this table means a strong association.

Probe tested	Performance index d_t
Verb-Object	2·10
Subject-Object	2·08
Verb-Subject	1·75
Verb-Location	1·52
Location-Time	1·18
Verb-Time	1·08

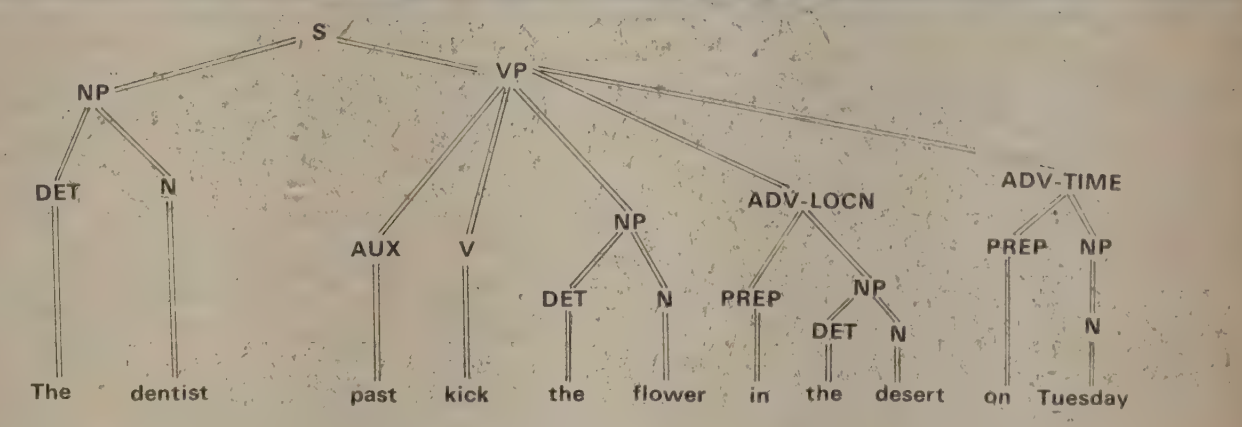


Fig. 12 A grammatical structure for the sentence given in Fig. 11. Aux = auxiliary; Adv = adverbs; V = verb; Prep = Preposition; NP = Noun phrase; VP = Verb phrase; DET = Determiner

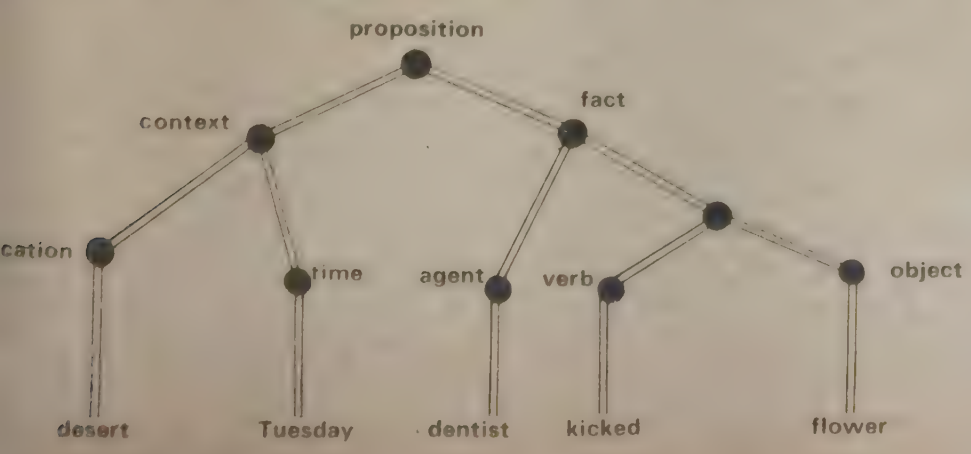


Fig. 11 Propositional structure for "The dentist kicked the flower in the desert on Tuesday." (From Dosher's paper)

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FOR FURTHER READING

The suggested reading list is divided into three sections: (1) Introductory, (2) Classical works, and (3) Others.

BIOLOGY

Introductory

1. Wooldridge, Dean E. (1963) *Machining of the Brain*. McGraw-Hill.
2. *Psychobiology: Readings from "Scientific American"*. W. H. Freeman & Co. (Has several interesting articles on the brain and memory.)

Classical works

3. Russel, W. R. (1959) *Brain, Memory, Learning*. Oxford Univ. Press.
4. Penfield, W. and Roberts, L. (1959) *Speech and Brain Mechanisms*. Princeton Univ. Press.

Other works

5. John, E. Roy (1967) *Mechanisms of Memory*. Academic Press.
6. Agranoff, B. W. "Memory and Protein Synthesis" in *Scientific American* (June 1967, Vol. 216, pp. 115–122).
7. Gazzaniga, M. S. (1970) *Bisected Brain*. New York Appleton-Century-Crafts.
8. Young, J. Z. (1966) *The Memory System of the Brain*. Univ. of Calif. Press.

PSYCHOLOGY & COMPUTER MODELS

Introductory

9. Hunter, I. M. L. *Memory*. Penguin Books.
10. Lindsay, P. H. and Norman, D. A. *Human Information Processing: An Introduction to Psychology*. Academic Press.

Classical works

11. Bartlett, F. C. *Remembering*. Camb. Press.
12. *The Neurophysiology of Lashley* (S *Papers of K. S. Lashley*) Ed. by F. A. *et al.* McGraw-Hill.
13. Lenneberg, E. H. *Biological Foundat Language*. Wiley.
14. Hebb, D. O. *The Organisation of Beh* John Wiley (Paperback by Sc Editions).
15. James, William. *The Principles of P -logy*. Holt (Reprinted by Dover).

Other works

16. Anderson, J. R. and Bower, G *Human Associative Memory*. John Wil
17. Dosher, B. A. "The Retrieval of Sent from Memory: A Speed-accu Study", in *Cognitive Psychology*, V (1976).

Mnemonics: looking into memory aids

"How I wish I could recollect to places eight. . . ."

Some 25 years back, in school, the mathematics teacher had made us memorise those despairing nine words. My memory still retains them. The sentence, strangely, meant nothing, in the sense a grammatically constructed sentence is supposed to mean something. Those nine words stood for nine numbers, each represented by the number of letters in a word: 3 1 4 1 5 9 2 6 5; this is the value of π, if you put a decimal after 3, to eight decimal places. It was a trick, or shall we say, an 'aid', to remembering. Similar aids are used by some of us to remember, say, a telephone number: "All the roads lead to Rome" — 33 54 24. Most of us do not use such aids — and these can range from simple codes to highly associative mnemonic systems — because we do not know how to go about organising items we *want* to remember. Perhaps this is what makes people fill in the coupons in those newspaper ads that claim to *own* the 'secret' of improving memory — memory kits, memory courses, and so on. There is no secret formula of improving one's memory: it was known to the Greeks a couple of thousand years back. In 1891, William James wrote, perhaps, the last word on it: "*All improvement of memory consists in the improvement of one's habitual methods of recording facts*". That's all there is to it, including those amazing skills displayed by stage performers calling themselves the "Memory Men".

The prerequisite to improving one's memory is to condition oneself to paying increasing attention to relevant information. Attention has two components: (*i*) learning to better focus our attention and eliminate distracting and irrelevant sources of stimulation, and (*ii*) increasing our ability to detect what must be remembered and what needn't be.

What are the main types of material that require attention in order to be memorised? We could say, names, numbers, lists, everyday information and text-book material.

Recalling a face is easier than remembering a name. The face can be recognised as having been seen before, but a name has to be associated with something, say, a situation, or the face itself. So to remember a person's name, we have to learn to remember the individual features of a person's face, and of the person's name, and establish some connection between the two. The characteristics that should be remembered as relevant are not things like good looks, or dress or height, but *distinctive* features which set a person apart. (Remember, cartoonists make use of this attention-focusing ability to draw out a personality through just a few strokes of a sketch pen!) Attending to a name is more difficult and one can look for one of three clues: (*i*) Is it an unusual name?, (*ii*) Is it a common name? or (*iii*) Does the name, in some way, fit the face? A sure way of focusing attention to a name heard is to repeat it, preferably sentence like, "It's a pleasure meet you, Mr. Sahay"!

When it comes to commiting n bers to memory, attention can focused on them by detecting *rela ships within a particular number* you to remember. Take 753147. notice the first three decrease by the last three increase by three. all numbers have such obvious r tionships, but if you are attentive, can almost always find one. 342516. You can easily work ou relationship by pairing the numb 34 25 16 — each right-hand decreases from the previous pair b

Remembering a list is quite remembering people's names, ex that while names have to be attac to faces, lists have to be remembe as a series, and where required serial order. In learning pairs, we for similarity between the two ite In a series, we look for simila among all the items. Say, you hav remember a shopping list contain potatoes, apples, grapes, peas, pepper, spinach, oranges and cin mon. You can organise the list three groups: vegetables, fruits, co ments, each group having three ite Now it becomes easier, doesn't it?

Where order is important, attent must be focused not only on individual items but also on items before and after. We shall disc some specialised aids to this in section on 'mnemonics'.

Organisation

An interest aspect of retrieval of information fr memory is that the task depends t great extent on the *way* the inform tion was learnt. If one has to orga incoming information into their p per niche, it is necessary to use pre-established system.

The oldest system of organisation "chunking". It is fairly estabshed that the maximum number of ems one can learn by rote is seven; ie number can be increased severalld, if the items can be grouped into chunks'. To prove our point, we can y the experiment below.

Read the following numbers, then ok away from the page and immeately try to recall them in order:

7, 4, 9, 5, 1, 6, 8, 3, 9

all likelihood you will not be able recall all the nine numbers, as they ceed the capacity of your shortrm memory.

Now if you were to chunk the mbers into groups of three each, call would be much easier. Try the llowing:

(749), (516), (839)

ecall here would be easier because u are handling *three* groups and not ne individual numbers.

However, chunking by itself will t help much if learning the list is t done actively. And active particiion of the learner depends on his scovering some interesting feature d storing it in the memory. As for stance, scan the following list,

1, 9, 2, 8, 3, 7, 4, 6, 5

Did you notice anything interesting? ne series begins with the lowest follow- by the highest digit, then the next west followed by the next highest, d so on. Several hours or days later, u are sure to be able to recall the t!

nemonics

Besides chunking, ere are two other techniques of ring information in long-term meory: (1) mediation, and (2) mneonics. Mediation involves creating link between items that you want remember as belonging together. nemonics is a specialised predeterned system of placing items to be membered in a rhyme or a story or artificial schema.

Mnemonic systems have been own as *memoria technica* or artificial mory. Most of the present-day urses or kits of memory improveent use these, though few of us are vare that they were known to the cient Greeks.

Let's start with 'mediation'. The st common form of mediation is to ild a bridge — insert a word, say — between two items, which normally do not have a verbal relationship. Which is the capital of Poland? It's Warsaw. How would you remember that? World War II started with Germany's attack on Poland. So you remember Poland and WAR. Now the capital will always be easy to recall. This is only an example. You can find and establish such mediative links between almost any two (or more) items of information.

Mediation works rather well with numbers. The technique basically is to transpose each digit into a predetermined letter, and then combine the letters to form a word or words (with the vowels inserted in between). Let us take the word ROUND. The consonant R stands for 4 (the vowels *O* and *U* are of no importance), and N stands for 2 and D for 1. So, ROUND represents 421. It's easier to remember ROUND than 421 (say, the number of a hit-and-run car) because it has 'shape'. The code in this system varies from mnemonist to mnemonist, but we can adopt a fairly consistent one, as follows:

1 = t and d; t has a vertical stroke and d sounds like t.

2 = n and x; n has two vertical strokes and x has two diagonal strokes.

3 = m and w; m has three vertical strokes and w is m turned upside down.

4 = q and r; r is the last word of four, and the Latin word *quartus* = fourth.

5 = s and ss; s looks like 5.

6 = b and p; b looks like 6 and p sounds similar to b.

7 = f and v; f looks like 7 reflected in a mirror and v sounds like f.

8 = h, ch, c and j; h sounds like 8, and j follows the vowel i; c often combines with h.

9 = g and k; g looks like 9 and k sounds like g.

0 = z and l; z for zero and l is left-over.

(We put Y amongst the vowels A-E-I-O-U-Y).

After you have learnt the code; you may have to use a little imagination while forming the word. Take 421. It can be written as r-n-t or r-x-d or q-n-t or q-x-d. Since both q and x are rarely used in fast word-construction, we choose r-n-t (or d): runt, rind, round. Round is better. It gives a shape.

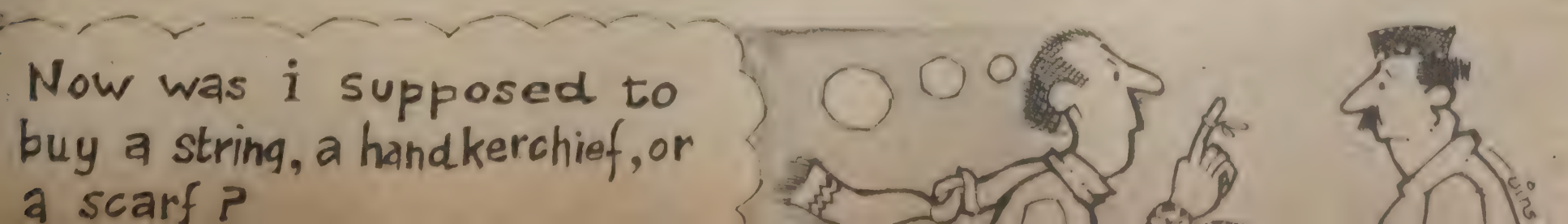
"Shall we send them lesson No. seven ? I've already sent three reminders to pay up the final instalment!"

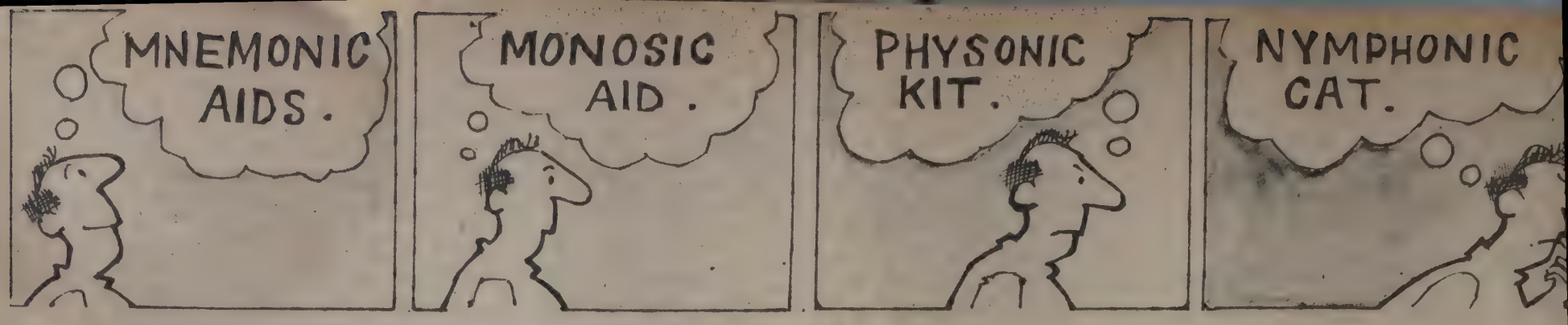
When there are many numbers, it's best to work with groups of three numbers while writing them into words. A four-digit number can be easily remembered by two words (a word for each pair). Take someone's birth date:
21. 4. 63 = NoTRe BuM (easy to remember since it reminds you of Notre Dame).

In mnemonic literature, one can find extensive tables of substitute words for all the figures between 1 and 1,000, and figures for every date in history — running into several pages. It would be advisable if you do not try to learn them by heart. It would be more rewarding if you devise your own code-words.

This type of digit-letter system is very old (the published reference dates back to 1684 when von Winckelmann of Germany published his 'most fertile secret') and has appeared in several forms, including the well-known (in UK) *Metrical Mnemonics* of Brayshaw, an English clergyman, which contained a collection of rhymes on over 2,000 dates and numerical facts drawn from history, geography, physics, astronomy, etc.

What the digit-letter system seeks to achieve is to fix an association according to a predetermined code. A similar but older method is the visual-symbol system, said to have been discovered by the Greek poet Simonides around 500 BC. It is also known as the 'locality' or 'house' system. Simonides stumbled upon the idea after he was able to identify the badly multilated bodies from a house collapse where a feast was going





on (he, too, had attended it but had left earlier) by recalling *where* each guest had been seated. In other words, if you wish to recall a series of names of people or objects, prepare the mental map of a room or a house and place the objects, each in a particular room or spot and, later on, as you recall the map, the object placed (mentally) in a location will automatically leap to your mind.

For an example, take the list: horse, cat, boat, tree, bear, dictionary, spectacles, hair brush, rose, bulb.

Now think of a house, preferably your own or one you know well. Imagine a HORSE tied to a post in the foyer. (What is a horse doing in a foyer? But, that's exactly it: the more bizarre the association, the more likely it is to stick in your mind!) From the foyer you move on to the living room. A CAT snuggles on the sofa. Next we move to the bathroom. There's flowing water and a tub. You wish you had a toy BOAT to play with in the tub. The bathroom leads to a passage, where a forest scene hangs from the wall. TREES. Trees remind you of a forest and a BEAR. You can't forget the bear. At the end of the passage is your child's room with a large teddy BEAR. The next room is a library. Books. DICTIONARY. You need reading glasses and you always leave one pair on the writing desk. SPECTACLES. Then you move on to the bedroom. The first thing you do after you wake up is brush your hair. HAIR BRUSH in a bedroom which opens on to a balcony: a ROSE plant in a tub. You water it and straight ahead everyday you look up to see a street lamp. It has a BULB. Have you made your map? Take some time as you place each object in the list to be memorised in a particular location. Then move on to the next. It's a sure bet that you won't forget the list and its order even after days.

The 'house' technique will work for a variety of memory tasks, like grocery lists, errands to run, points to make when writing an essay during an examination or when delivering a talk, or naming objects shown in a party game.

The 'house' technique is a mental peg (or map) technique. Another popular one is the "one is a bun" technique. It is described rather colourfully in the facing page. This has great advantages. First, the mnemonic is in rhyme, that is, each representational word rhymes or sounds very much like the number. Second, it can be used again and again, and third, it can be extended to include more than ten items by doubling up on the images.

It must be emphasised here that mnemonics work only through prolonged practice. It does not matter which method you use — 'house', 'one is a bun' or any other, as long as you are able to comfortably put the one you have chosen to use.

How effective are mnemonic systems? After all, as we have seen, they are designed to help the learning requirements of particular tasks like long, random sequences of words, numbers, lists, playing-cards. There is no doubt that, as far as these tasks are concerned, mnemonic aids do help — mainly because one can transpose information items into other it (images or predetermined sche familiar to one and, therefore, ea to retain in long-term memory. the question remains: how effec are they in improving memory a whole? The answer, in all probabi would be, not enough, to be wo while. But, then, as I. M. L. Hu points out in his *Memory*: "' mastery of some mnemonic sys may lead some people to realise, the first time, that they can con and modify their own mental act ties. And this realisation r encourage them to undertake t self-critical examination with th own learning and remembering p cedures which is such an import part of intellectual development".

Before we conclude, one point ne to be noted. Mnemonic systems c

(Contd. on p.

Memory courses: a few questions

As the accompanying article points out, there are many different mnemonic systems. Some of these are described in bulky volumes which are sometimes offered as mail order courses. Priced in hundreds of rupees, such courses are proclaimed to be very profitable by bold advertisements. Readers might be interested in some comments on such courses.

Will a memory course make me a better scholar?

No. The essence of mnemonic systems is that they help in making you remember uninteresting details. They usually make these more memorable by dressing them up in a colourful form. Advancement in studies, on the other hand, requires that the scholar should be truly interested in what he is studying. Uninteresting details can easily be kept track of by acquiring a couple of handbooks and by keeping a pocket notebook.

Schools sometimes place too much emphasis on numbers. "In which year did Vasco da Gama reach India?" A memory course could help one to gain marks by answering such questions by using a memory system. There is, however, a better alternative. Instead of using bizarre associations of the numbers to buns or biscuits, it would be much more useful to approach the subject by reading a genuinely interesting book on the subject. When the numbers *become meaningful* to you, bizarre associations are no longer needed.

Can I really improve my memory?

One should not expect miracles here. Would you expect to use your salary much better from what you learn in an economics book? Well-known psychologists have felt that one can improve one's memory by gaining some knowledge of the subject. Reading a good book on psychology can clear up some misunderstandings and give some hints on how one can alter one's mental habits. By providing a framework of ideas for analysis and discussion and by encouraging one's efforts in organising ones activity, such books could make a positive contribution.

Are there cheaper alternatives to memory courses?

It is very easy to find inexpensive books written by genuine scholars. Hunter's book mentioned in the reading list (No. 9, p. 42) is a good example. Such books are almost always a better bet than memory courses offered by purely commercial mail order houses. The books are available at a fraction of the cost of the courses. A 'course', after you have paid for it, can turn out to be nothing more than a book much inferior to Hunter's.

For those who wish to study memory aids in detail, we suggest a couple of inexpensive books:

1. *Improving Your Memory* by Laird S. Cermak. 1976. McGraw-Hill Paperbacks.
2. *Conditioning Your Memory* by "The Memory Man" (Wolfgang Zielke). 1970. Cornerstone Library, New York.

S. RAMANI

DEVELOP A SUPERMEMORY : AMAZE YOUR FRIENDS

This artificial technique of memorising (a mnemonic technique, in psychological parlance) is probably very old. It is described by several books on memory (including our reference 9, p. 41). We can practically guarantee that any reader who spends 15 minutes with it can memorise any list of 10 items (or less) such as this shopping list:

1. Oil
2. Sugar
3. Soap
4. Kerosene
5. Tomatoes
6. Razor blades
7. Syrup
8. Eggs
9. Biscuits
10. A magazine

The technique essentially involves hanging each one of these items on a *mental peg* — a numbered mental peg. If you are asked what is the fifth item in the list, just look at mental peg No. 5. What comes after eggs? Just search to see the number of the peg for eggs and then look up the next peg. Do you want to reel off the list in reverse order? Just look at the pegs in the reverse order.

All we have to tell you now is the trick of the mental pegs. Read this rhyme, three times. You will never forget it.

One is a bun,
Two is a shoe,
Three is a tree,
Four is a door,
Five is a hive,
Six is sticks,
Seven is heaven,
Eight is a gate,
Nine is a line,
Ten is a hen.

These 10 objects are neatly associated with numbers because of the similarity in their sound patterns. What object is mental peg number nine? A line, of course, a clothes line. Hanging objects of a given list on these pegs is easy. Let us try the shopping list. Read the following associations slowly, visualising each one in turn. You need not look back at any association. Once you have visualised it, it will stick in your mind.

1. Oil: One is a bun. Imagine a bun soaked in oil.

2. Sugar: Two is a shoe. Imagine a shoe filled with sugar cubes.

3. Soap: A cake of soap pierced by the sharp point of a tree branch.

4. Kerosene: A door soaked in kerosene; it may catch fire.

5. Tomatoes: There is a beehive on the tomato plant.

6. Razor blade: You are sharpening a stick. It reminds you of a blade.

7. Syrup: A cool drink on a hot and thirsty day — you are in heaven.

8. Eggs: Egg-shaped Humpty-Dumpty sitting on a wall next to a gate.

9. Biscuits: Hung from a clothes line, with laundry clips.

10. A magazine: You want to read it, but a hen is sitting on it possessively.

Finished? You can now hand over the SCIENCE TODAY to someone else and demonstrate to him your supermemory. What is the fifth item on the list? What comes before biscuits? Do we have bananas in the shopping list? What is the list in reverse?

S. R.

Sushma

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CLEAR PHYSICS

in Effects in Proton-oton Scattering

n experiment that may be a forerunner of others leading ultimately to the elucidation he structure of the proton has been orted by a large team of physicists he *Physical Review Letters* (**39,** 733, September 1977). They have wn that proton spin has a large curious effect on the way one ton bounces off another.

Spin is one of the fundamental perties of sub-atomic particles. It ys a small but important role in clear and atomic structure. The sent understanding is that spin plays y a minor role in proton-proton stic scattering. But, J. R. O'Fallon, G. Ratner and P. F. Schultz of gonne National Laboratory, USA, Abe, R. C. Fernow, A. D. Krisch, A. Mulera, A. J. Salthouse, B. ndler and K. M. Terwilliger of the iversity of Michigan, USA, D. G. abb of Oxford University, England, d P. H. Hansen of the Niels Bohr stitute in Copenhagen, Denmark, ve from their experiments obtained ults, surprisingly, quite contrary.

They bombarded a polarised proton get with a polarised proton beam ins oriented in the same direction) oduced in the Zero Gradient Syn-rotron at the Argonne laboratory. ey used a 70 per cent polarised oton beam of energy 11·75 billion ctron-volts and a 65 per cent larised proton target. They de-cted by means of a double-armed agnetic spectrometer events where e polarised-proton beam is elasti-lly scattered from the polarised-oton target. From an analysis of easurements, the effects of spin were und most pronounced when the ouncing proton came off at a large gle to its original direction and at gh energies.

The protons bounce rather well off ch other when their spins are arallel. When the spins are anti-arallel, the protons appear to ass right through each other, as if ey were transparent. Their data, fact, indicate that the spin parallel teraction dominates the antiparallel teraction by a factor of two at a erpendicular momentum of 4·0 illion electron volts. They speculate om the combination of high energy nd high scattering angle that some-ing rather deep inside the target roton is responsible for the observed ffects.

The results could be explained in terms of spinning charged clouds in protons or in terms of point-like constituent quarks with spin. On the quark-parton model, protons are indeed composed of three fractionally charged particles called quarks. Are quark spins responsible for the observed effects? What is the size of the quark? Only future experiments may be able to provide answers to such highly speculative questions.

MOLECULAR BIOLOGY

Synthesising an RNA Tumour Virus

RNA tumour viruses created history nearly a decade ago when it was shown that they can invade a cell and take over its machinery to reproduce themselves. They seemed to violate a fundamental dogma of molecular biology that DNA of which genes are composed is initially transcribed into a "messenger" RNA molecule which is then translated into the specified protein. It was later found that DNA was transcribed from the virus RNA and this DNA got itself integrated with the cell's genetic mechanism. The conversion from RNA to DNA is accomplished with the help of an enzyme, now properly termed "reverse transcriptase". (See SCIENCE TODAY, December 1970, p. 9.) The enzyme was discovered by Dr. Baltimore and Dr. Temin and they were awarded the Nobel Prize for 1975 in physiology or medicine for the discovery. (See SCIENCE TODAY, December 1975, p. 30.)

Ever since the discovery of reverse transcriptase, biologists have been attempting to simulate the process of copying of RNA into DNA in the test-tube so that it could be studied in some detail. But so far they had succeeded in synthesising only short segments of DNA from RNA templates. It was hence suspected that it may not be possible to make a complete DNA molecule without the intervention of cellular factors. Some recent studies, however, indicated that improved reaction conditions allow detergent-disrupted virus particles to synthesise DNA molecules 8,000 to 9,000 nucleotides long, the length of the viral RNA which serves as template.

Ellen Rothenberg, David Smotkin, David Baltimore and Robert A. Weinberg of the Department of Biology and Center for Cancer Research, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, now report in *Nature* (**269,** 122, 8 September 1977) that they have finally succeeded in perfecting a system in which full-length double-stranded DNA copies of purified mouse leukaemia virus RNA are synthesised. They used only the virus particle as the RNA template and the enzyme reverse transcriptase. What is more, the synthesised DNA molecules were shown to infect mice cells and produce complete infectious virus particles, demonstrating that all the information needed to specify the virus has been correctly copied from the RNA to the DNA. They found that neither RNA nor protein is required for infectivity, but it depends only on DNA. They conclude, "reverse transcription in purified virions may accurately reflect the mechanism of synthesis of the viral DNA in infected cells".

ASTROPHYSICS

Cellulose in the Cosmos

Further support to the suggestion that molecules of life may have originated in the vast space between stars has been provided by Prof. Fred Hoyle and Prof. N. C. Wickramasinghe of the Department of Applied Mathematics and Astronomy, University College, Cardiff, UK, in an article in *Nature* (**268,** 610, 18 August 1977). They have presented evidence, though indirect, for the presence of cellulose, the chief component of the cell walls of plants, in interstellar matter.

More than three dozen molecules have so far been discovered in interstellar space and the number is steadily mounting. One property of the abundant molecules of formaldehyde (H_2CO) is that they can link together to form a complex chain (polysaccharide) by a process known as polymerisation. The resultant molecules can form stable ring structures such as starch and cellulose that are capable of resisting the degradation by ultraviolet radiation from stars. This radiation prevents most molecules such as H_2, HO and CO from existing for long periods in space.

While the point whether cellulose really forms in space in this way is disputable, astronomers have good enough evidence that the interstellar space consists of vast clouds of dust and gas. The British physicists have been studying, during the past few years, the absorption of infra-red radiation by dust grains. The results

he studies carried out by means of loons and rockets have been partiarly interesting in that the dust peared to absorb infra-red radiaı strongly at two wavebands, cened at 3 microns and 10 microns. ese were identified as due to water- and magnesium silicate, respecely. It was thus natural to attribute infra-red properties of interstellar st to a mixture of water-ice partis and magnesium silicate grains. t it was later found that the tailed correspondence of a silicate- model to the observed infra-red ectra of a wide range of galactic urces is not good. The discrepancy s intriguing since silicate and ice simple materials.

Cellulose, being of economic imrtance to the cotton industry, has en studied extensively at infra-red velengths in the laboratory. Hoyle d Wickramasinghe have now comred the properties of interstellar st at infra-red wavelengths with the operties of cellulose-like materials these wavelengths. They found that infra-red absorption of cellulose-e materials occurs at exactly the ne wavelengths (3 microns and 10 icrons) as that of interstellar dust. was also possible to explain in some tail the infra-red spectra of a mber of sources on the assumption at cellulose is indeed present in the terstellar matter. They could readily late astronomical data in the 2–4 icron, 8–13 micron and 15–30 icron wave bands.

They state that " the identification this highly complex macromolecule uld have a profound bearing on terstellar chemicals including the olution of prebiotic molecules ".

IEDICINE

an Chronic Bronchitis revent neumoconiosis?

Pneumoconiosis is an occupational hazard of coal miners and is caused by the inhalation coal dust. Coal miners are also bject to chronic bronchitis, the asons, besides the dust exposure, ing tobacco smoking, air pollution nd respiratory illness during childood. The clinical role of bronchitis to mask the ventilatory function sts in simple pneumoconiosis. In ct, some epidemiological studies had ggested that bronchitis might ineed have a protective action against ne development of pneumoconiosis. . C. F. Muir, J. Burns, M. Jacobsen nd W. H. Walton of the Institute of Occupational Medicine, Edinburgh, Scotland, have in a report to the *British Medical Journal* (**2,** 424, 13 August 1977) tested the above hypothesis, using data from a major long-term epidemiological survey in the British coal mining industry.

The study included 4,883 men who were radiologically examined initially for the presence of simple pneumoconiosis. The presence or absence of persistent sputum in them was also ascertained by a questionnaire. The men were again examined ten years later for pneumoconiosis. The dust inhaled by individuals during the ten year period was calculated from dust sampling results and detailed records of attendance at work. The amount of exposure to dust by the individuals before the commencement of the survey was estimated from information on earlier industrial histories. The amount of dust inhaled (gh/m^3) was obtained by multiplying measured airborne concentrations (g/m^3) by the number of hours worked.

The results of the initial survey indicated that, as expected, there was a greater proportion of men with persistent sputum among those with pneumoconiosis. Confining only to the 4,356 men with no pneumoconiosis in the initial survey, it was observed that 11 per cent of those with persistent sputum present developed pneumoconiosis ten years later, as compared to 7·3 per cent in those with no persistent sputum, despite the fact that the former group had slightly lower dust exposures on the average. Their results were thus in contradiction to the hypothesis that sputum production protects against pneumoconiosis. In fact, they present evidence that the probability of developing pneumoconiosis depends on the cumulative exposure to respirable dust and was little affected by the presence or absence of symptoms of sputum.

The Scottish doctors conclude that their results are compatible with a simple model in which dust in coal mines may cause pneumoconiosis, bronchitis or both. According to them, it is unlikely that airflow obstruction, irrespective of mucus hypersecretion, has a protective action.

BIOCHEMISTRY

A Desert Shrub Grows Rubber

A team of chemists from the Fruit and Vegetable Chemistry Laboratory, Western Region, Agriculture Research Service, Pasadena, California, USA, and the Jet Propulsion Laboratory, Pasadena, have demonstrated in an article in *Science* (**197,** 1076, 9 September 1977) the induction of natural rubber in the desert shrub guayule (*Parthenium argentatum*) by treatment with the chemical 2-(3, 4-dichlorophenoxy)-triethylamine. (See also SCIENCE TODAY, June 1977, p. 9.) Their results suggest that the production of rubber can be increased by the use of chemical agents on guayule and other rubber-forming plants.

Guayule is native to the Chihuahuan Desert of north and Central Mexico and the adjacent Big Bend region of Texas. The plant can be grown in arid and semi-arid lands, and during the Second World War the plant was extensively investigated as a source of natural rubber in the United States. The programme, however, was terminated when synthetic rubber was developed.

H. Yokoyama, E. P. Hayman, W. J. Hsu, S. M. Poling and A. J. Bauman have reported the results of tests on entire seedlings (four months old) grown in the greenhouse and of subsequent experiments on field-grown guayule plants (eight months old). The seedlings were treated with 5,000 ppm of 2-(3, 4-dichlorophenoxy)-triethylamine, 5,000 ppm of 2-diethylaminoethanol and a wetting agent. Controls were treated only with 2-diethylaminoethanol and the wetting agent. The former chemical appeared to influence the magnitude of the plant response to 2-(3, 4-dichlorophenoxy)-triethylamine. The plants were harvested three weeks after treatment and were in a state of vigorous vegetative growth when the rubber content was analysed. They found a two- to six-fold increase in the amount of polyisoprenoid rubber accumulated in the stems and roots of the treated plants. The rubber was present as a latex in parenchymatous cells.

The American chemists state that in accordance with the results of other experimenters on guayule plants, the magnitude of response in field-grown plants may be greater when treated during periods of water stress or dormant growth than during periods of vigorous vegetative growths. Also, larger yields may be expected from plants more than a year old. The resins of this plant may also be as valuable as rubber since they contain terpenes—important chemical intermediates. However, the effect of triethylamine on the composition of the resin fraction still remains to be explored.

K. A. NEELAKANTAN

PUTTING THE SHOT DISCUS-STYLE

JAL D. PARDIVALA

The credit to "view with the mind's eye the discus style shot putt technique" definitely goes to the Russian Alexander Baryshnikov who was the first successful exponent way back in 1972. With this technique (at Montreal, 1976) he claimed the bronze medal with a throw of 21 metres (68 ft 11 in), though in the qualifying rounds he had established a new Olympic record of 21·32 metres (69 ft 11·5 in). Just prior to the Montreal Games, on 10 July 1976 at Paris, he established a new world record of 22·00 metres (72 ft 2·25 in).

However, the longest throw in the world has been achieved by the American Brian Oldfield, who had putt the shot to an amazing distance of 22·86 metres (75 ft) in a professional track meet held on 10 May 1975 at Al Paso, Arizona, USA. Oldfield had achieved this mark through the "rotational technique" — said to be an improvement on the Obrien style. Parry Obrien's idea was to bring in more power by going further and further back in the ring and facing more and more backwards. According to Oldfield, the "rotational technique", which is a pivot at the back of the circle, gives an extra 3 feet (1 metre) advantage to the thrower's motion.

Here is a photographic analysis of his throw:

(1) Picture one is a stance at the back of the circle, the typical discus turn with the body weight initially on the right foot. A slight rotation of the upper body to the right is visible.

(2) The beginning of the 'discus style spin', pivoting on the left foot around the toes. This movement, according to a technical ex enables the thrower to extend range of the "momentum-gai phase", that is, to accelerate the as soon as the right foot takes off.

(3) Half-way through the turn, drive from the back of the ci towards the centre begins. gives "the important linear d through the circle".

(4) The right leg lands near centre of the circle to begin greatest implementation of anot turn which according to Oldfiel 360°. Landing on the right toe, C field is trying to come all the w round to a forward position.

(5) Here he is half-way through final turn. Two points to note a (*i*) the upper body is not only o the hips but also over the right kn and (*ii*) this position is almost simi

(Below) The conventional shot-putt technique. (Right) Photo series of Brian Oldfield's 'rotational' throw

1

2

4

5

the Obrien style position in the act gliding. (See Figs. 3 and 5, " The ence Of Shot Putt ", SCIENCE DAY, February 1977, pp. 47–49.) the picture, the left foot of Oldfield about to come down. Oldfield ieves that in the rotational tech- que, the putter not only has 3 feet m) extra advantage in the initial ges of the whole movement, but HE HIPS SLIDE INTO POSI- ON MORE EASILY.

(6) This stance is equivalent to the rien style, except that the left foot s gone very much in the bucket rticularly in this picture which not correct. The body mass is still the right leg, though he is on the int of starting the rotation of the nk. The right elbow is exactly hind the shot and is almost at an gle of 45°. The little finger and the umb are opposite each other. The t arm is locked-in to prevent ther unwanted rotation.

It is believed that when the otational technique " is faultless, od results are achieved. But, as

one coach sums up, " faults such as loss of balance and inaccurate foot placement caused by insufficient leg strength are, however, heavily penalised by very poor results, and also, of course, uncontrolled shots while taking the turns can be dangerous to onlookers and others."

And talking about discus... Al Oerter is back!

Remember Al Oerter? Four times Olympic champion, the first man to exceed 200 ft (60·8m), the " nonpareil of discus throwing "? Our article on discus throwing (SCIENCE TODAY, May 1977) had begun with a quote from Melvin Watman's *Encyclopaedia of Athletics:* " He seemed destined for greatness when he set an American schoolboys' discus (3 lb 9 oz = 1·6 kg) record of 184 ft 2 in (56m) in 1954; but few could have anticipated he would develop so speedily that only two years later (at the age of 18) he won an Olympic gold medal. His repeat victory in 1960 was less surprising. Oerter's third triumph in 1964 ranks amongst the greatest competitive efforts in athletic history for he was in acute pain.

" His achievement in winning an unprecedented *fourth* Olympic title in 1968 made him the most outstanding competitor in the annals of athletics. . . . It was not until 1962 that he laid claim to the world record. He made history by throwing 200 ft 5 in (61·10m), lost the record 17 days later to Vladmir Trusenyov of the USSR, and recaptured it with 204 ft 10 in (62·3m) — after a further lapse of 27 days. He improved it to 205 ft 5 in (62·5m) in 1963 and 206 ft 6 in (62·8m) in 1964 for further world records. . . . It was a relief to those with 1972 Olympic aspirations that Oerter decided not to try for the fifth victory."

The ' relief ' wouldn't last. Al Oerter is now hoping to make the 1980 Olympic Games at Moscow.

Al Oerter left the athletic arena in 1969 to spend more time with his two young daughters. Seven years would pass. In 1976, Oerter was taking part in a filming session with Bud Greenspan during the making of a segment for *The Olympiad* television series. After the filming, Oerter realised he simply wanted to throw the discus again. After a couple of false starts, he sat down and mapped out a time-schedule. " I don't think I've been out of condition since I was eight years old," he said. " This year I'd like to throw 200 ft (60·96m), next year 215 ft (61·54m), the next 225 ft (68·58m), and 235 ft (71·64m) in 1980. If I can reach these goals, it will put me in a class that — given the right conditions — anything can happen. . . ."

In April this year, Oerter had surpassed his 1977 target by throwing 205 ft 1 in (62·52m), his best mark since winning at Mexico City in 1968. The mark is, of course, far behind Mac Wilkins's world record throw of 232 ft 6 in (70·86m) established last year. Al Oerter will have to work hard indeed.

How does he plan to go about it? " I will keep working on strength, then I'll start throwing the 35 lb (15·75 kg) weight. It's complementary to the discus because you have to be fast in the ring to throw the weight. Not only is strength difficult to regain, but I'll have to increase mine by 25 to 30 per cent. I won't throw in any more big meets this year, just some development meets at St. John's where I can pay my quarter and throw. That way I can throw or lift the night before and not worry about technique. I'll start throwing with the fine discus throwers next year. I suppose I could throw 210 ft this year, but then I'd probably throw only 211 ft next year. It's a building thing."

And talking about 1980, Al Oerter is realistic: " It's going to be tough to get up there with Mac (Wilkins)."

tube that tells on ɔplers

A simple device for screening drivers of motor vehicles for alcohol consumption may ve a boon to traffic police conɔles. It has been developed by the ntral Scientific Instruments Organion (CSIO), Chandigarh.

Many road accidents are due to the nkenness of drivers whose effincy and judgment is impaired by consumption of alcohol. The contration of alcohol in the blood is ost universally accepted as a able indicator of intoxication, but s not always possible or convenient conduct blood tests. Fortunately, relationship between the level of ohol in the breath and that in the od has been found to be reasony constant for practical purposes. erefore, in many countries of the rld, breath alcohol analysis tubes ve been adopted for the determinan of the blood alcohol concentran for several years. In the United tes, people can be convicted on the sis of the breath analysis alone. In st countries, a blood alcohol level 30 mg per 100 ml has been accepted the legal level for convicting rposes.

The device developed at the CSIO in the form of a small disposable ss tube. It detects alcohol in the eath and provides immediate inmation whether or not the driver spected of having consumed alcohol ould be sent for blood examination. e gadget can be used for simple adside screening tests. If the test is sitive, the person could be taken the police station and asked to ovide a specimen of his blood or urine. If the alcohol level in the blood exceeds 80 mg per 100 ml of blood, he may be convicted.

The gadget consists of an indication tube containing a yellow-coloured substance and is accompanied by a breathing bag and a mouth-piece. The person to be tested for drunkenness is asked to blow through the mouth-piece till the bag is fully inflated. It takes 10 to 20 seconds to completely inflate the bag. The blood alcohol concentration is indicated by the yellow substance turning green almost instantaneously. In case the blood alcohol level exceeds 0·08 per cent or more, the discoloration reaches the red band marked on the tube. The extent of change of colour of the tube is proportional to the concentration of alcohol in the blood.

Extensive tests with this device have been carried out at the Post-graduate Institute of Medical Education & Research (PGI), Chandigarh, by analysing the blood alcohol level in the human subjects after administering a measured quantity of alcohol to them. The experimental results excellently correlated with the level indicated by the tube. A few sample tubes were given to the Chandigarh and Haryana Police Departments for field trials. These trials have been found satisfactory and a few persons have been convicted on the basis of this device. Various state governments in the country have expressed interest in this gadget for mass scale applications.

The design of the gadget has been perfected and the know-how released to a public sector undertaking.

The operation of the gadget is very simple. The traffic police constables would experience no difficulty in carrying out the tests on the roadside.

The tube is disposable and can be used only for one test.

maybe a peg too many?

New technique for sulphur dioxide removal

Sulphur dioxide in the atmosphere in excess amounts is bad to human health. And the increased use of coal following the high price of oil can cause increased SO_2 emission in the atmosphere. Though lime is now used to scrub flue gases industrially, the process does not remove all the SO_2. Several other processes to remove SO_2 from stack gases have been proposed, but none has attained a commercial status.

A new process which uses iron sulphide for SO_2 removal has recently been reported (*Chemical & Engineering News*, **55** (22) 24, 1977). Iron sulphide is abundant in pyrite mine tailings, and disposing of it is a problem. It can be used to recover sulphur from stack gases. The process is based on a gas-solid reaction between sulphur dioxide and a sulphide of iron. The solid is mixed with the stack gases as an atomised slurry. The reaction product is an unstable compound which precipitates out. A final step reconstitutes the original iron sulphide, leaving pure marketable sulphur.

The process is 90 to 98 per cent effective in removing sulphur dioxide. The process is efficient between 40 and 4,000 ppm of SO_2, while most other processes need at least 400 to 500 ppm. The process also consumes less energy. The flyash left over is not of objectionable composition and the residual carbon in the flyash is a useful reductant in the regeneration step.

The capital and operating costs are estimated to be one-half to two-thirds of other regenerable systems such as carbon reduction. The process could be wet or dry; the system could be regenerative or non-regenerative, that is, a small company could build only half the system and send the precipitate to a central system for recycling or just discard it as land-fill. The precipitate will be much easier to handle than the limestone sludge in the conventional method using lime, where the sludge is in a slurry form.

Pilot plant trials of the process have shown good promise. An integrated facility is being set up at a Westinghouse plant in Pittsburgh, USA. If the process really shows all the advantages expected, it will help several countries utilise their huge deposits of high-sulphur coal.

V. C. MALSHE

NEXT MONTH

A special section on

STATISTICS & THE COMMON MAN

and a revealing article on teaching science in village schools

THE HOSHANGABAD VIGYAN—A UNIQUE EXPERIMENT

HOW GOOD ARE OUR ELECTRICAL APPLIANCES

P. J. JOGLEKAR
S. T. PATIL

Food mixers and grinders, washing machines, hair dryers, shavers, etc are all motor-type appliances. The heart of all motor-type appliances is the fractional horse power electric motor (1 horse power = 746 watts). A typical washing machine uses a motor of 1/8 to 1/3 horse power. Typical food mixers use motors which consume about 300 to 400 watts. Hair dryer motors consume about 100 watts.

There are various types of fractional horse power motors. The motors used in mixers are called universal motors (see box). They can operate on both AC and DC. They are series motors capable of operating at very high speeds of the order of 14,000 to 18,000 rpm (revolutions per minute). On the other hand, washing machines use induction motors which work at a speed of about 1,400 rpm. Motors used in hair dryers are of the universal type, whereas in shavers synchronous motors are used which work a constant speed.

Motors operating at high speeds in mixers, must rotate smoothly. this, there has to be a comp circular symmetry in its rotor. Thi called balancing. If this balancin not proper, the motion during complete revolution is not smooth jerky. This causes unequal stress the bearings which support the ro Obviously, there will be uneven w and tear which will cause furt imbalance and the machine will damaged in a short time. To av this, it is necessary to balance rotor very accurately. Electronic namic balancing machines are v efficient. However, most of the ma facturers in India do not use th machines. This is why their mot are not as good as they should be.

The manufacture of stator windi also needs attention. Vacuum i pregnation technique must be used reduce losses and increase insulatio In our survey, we found that even progressive and enlightened man facturer was using only ordina impregnation.

It is not that these techniques a very new or unknown but it appea

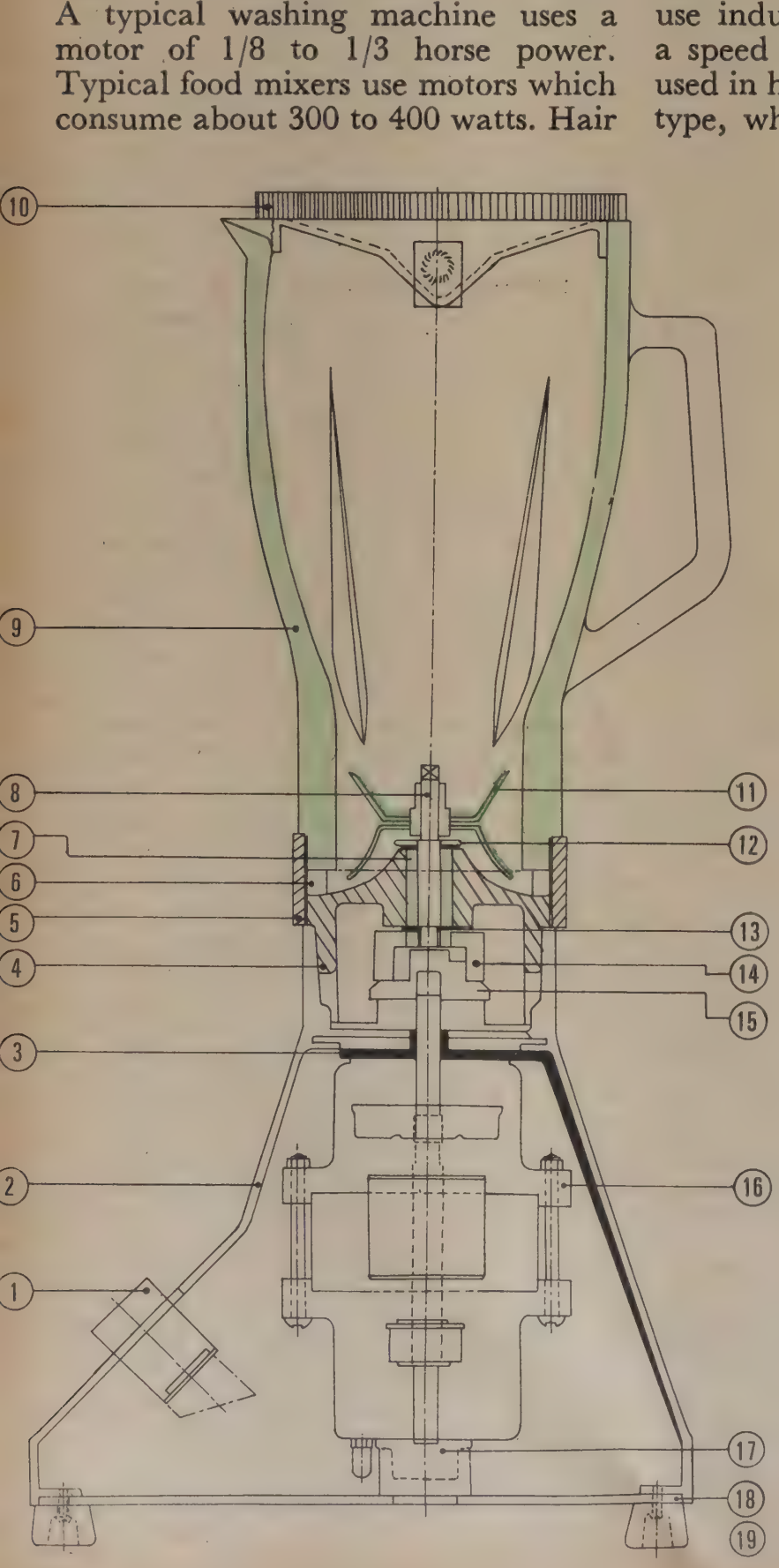


Fig. 1 (left) The constructional details of a food mixer/grinder. The numbered parts are: (1) switch assembly (2) body (3) bypass (4) cup (5) skirting (6) ring (7) bush (8) spindle (9) jar (10) cover (11) liquidiser blade (12) cap (13) washer (14) coupling driver (15) coupling driver (16) motor assembly (17) motor support (18) base plate (19) mixer support and (20) aluminium jar

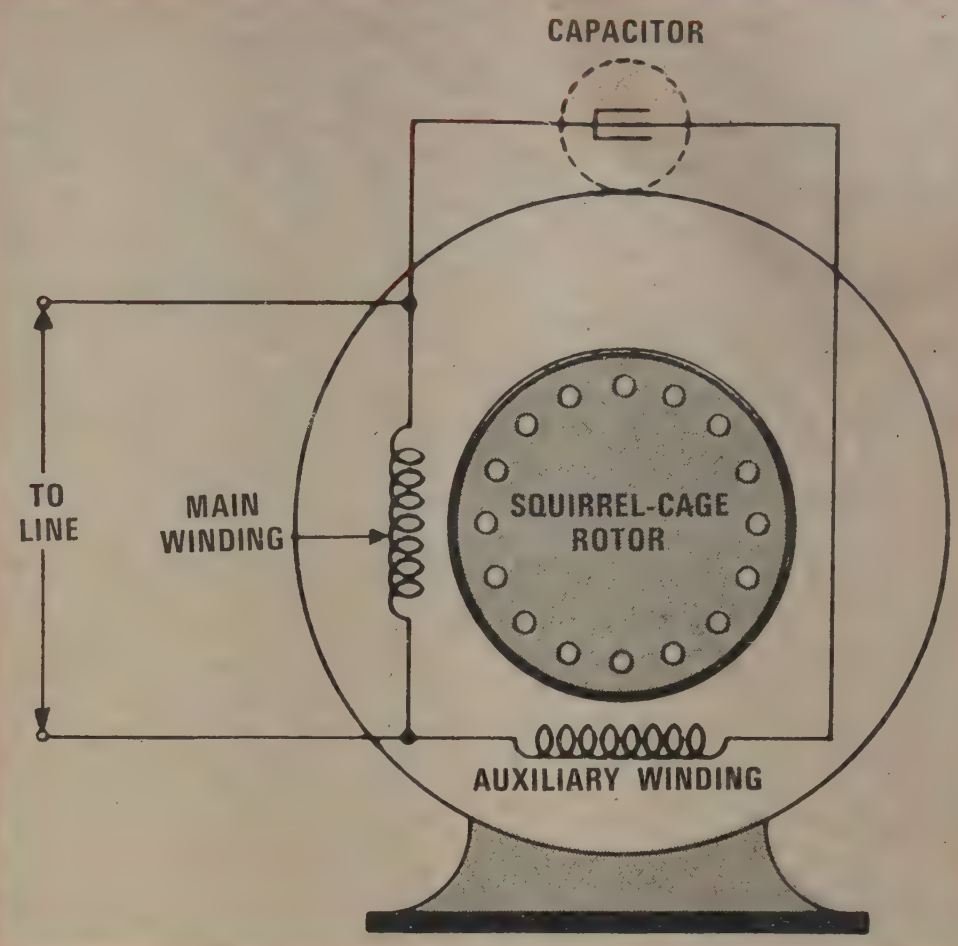
Fig. 2 (right) The food mixer/grinder

FRACTIONAL HORSE POWER MOTORS

An electric motor converts electrical nergy into mechanical motion. This based on the well-known principle nat a current-carrying conductor laced in a magnetic field experiences force in a direction perpendicular to oth the directions of the electric urrent and the magnetic field.

DC series motors and 3-phase AC nduction motors are the commonly mployed types in large motors. But here are a host of industrial and domes-c uses of electricity which require nly a small amount of power. For hese applications, fractional horse ower motors are used which work on ngle phase supply.

Universal motors are similar to DC eries motors and they can work on C as well as AC supply. They are sed where speeds greater than 3,000 pm (revolutions per minute) are equired. The speed of these motors is uite high on no load and decreases ith increase in load. (DC series notors cannot be operated on no load t all as they can attain very high peeds damaging the motor. Universal notors usually do not reach such amaging speeds.) The speed of a niversal motor can be adjusted by onnecting a resistance of a proper alue in series with the motor. The peed changes with a change in load nd also with changes in supply voltage nd frequency. These characteristics



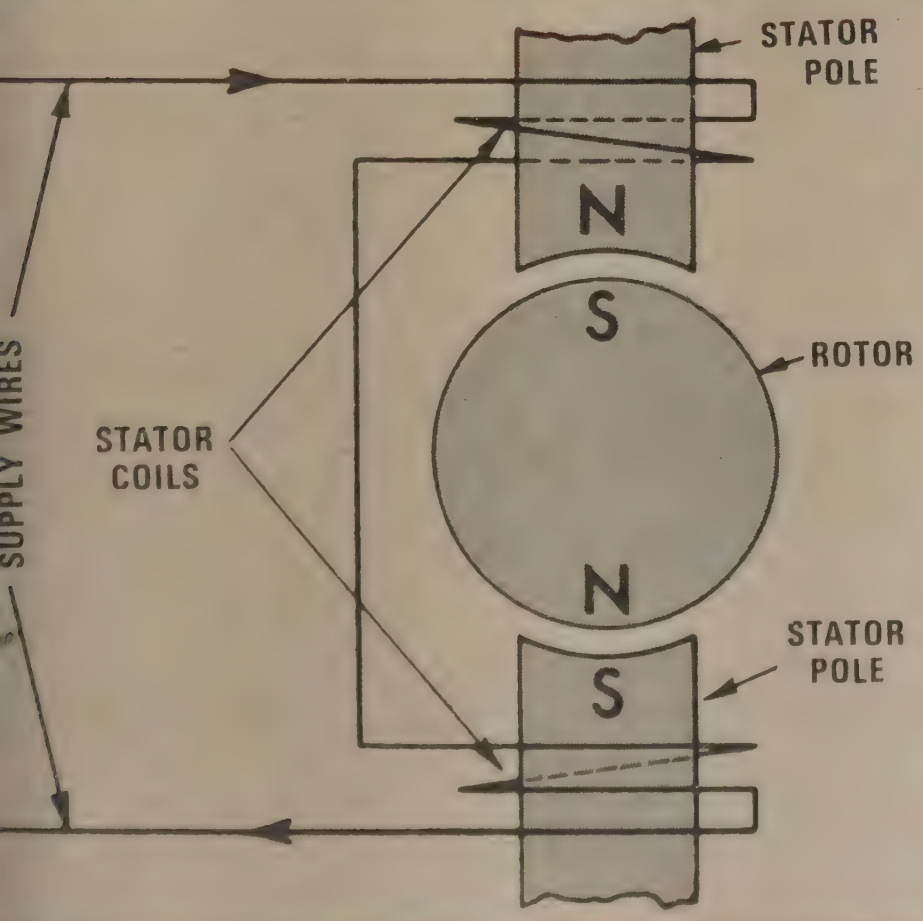
Permanent-capacitor split-phase motor

are undesirable in some applications and in such cases AC single phase motors are used.

AC motors are of two types — synchronous and induction. The speed of a synchronous motor depends only on the number of magnetic poles and the supply frequency $\left(\text{rpm} = \frac{120 \times \text{frequency}}{\text{Number of poles}}\right)$. A two-pole motor (one north pole and one south pole) will have a synchronous speed of 3,000 rpm for a 50-cycle supply. A synchronous motor is used in applications which require constant speed such as wall clocks and tape-recorders. Synchronous motors are not usually used in applications which need a fairly large amount of power and never where the speed must be controlled like in fans.

Induction motors work at speeds slightly less than synchronous speeds. In 3-phase motors, a rotating magnetic field is produced due to currents in the stator windings. This rotating magnetic field pulls the rotor. In single-phase motors, there is no rotating magnetic field. The simple unit is shown in the figure on the left. It would merely stand and hum without turning because the magnetic force is in the vertical direction and there is no lateral force to cause rotation. If, however, the rotor is turned rapidly by mechanical effort, a voltage is induced in the moving rotor conductors as they sweep across the magnetic field. The resultant current interacts with the magnetic field due to the stator, and the rotation is maintained. Single-phase induction motors are made self-starting by providing some additional features. A second stator winding called the starting winding is provided in split-phase motors. The capacitor motors, on the other hand, have an auxiliary winding connected in series with a capacitor across the supply (see figure).

P.J.J.
S.T.P.



A simple single-phase motor

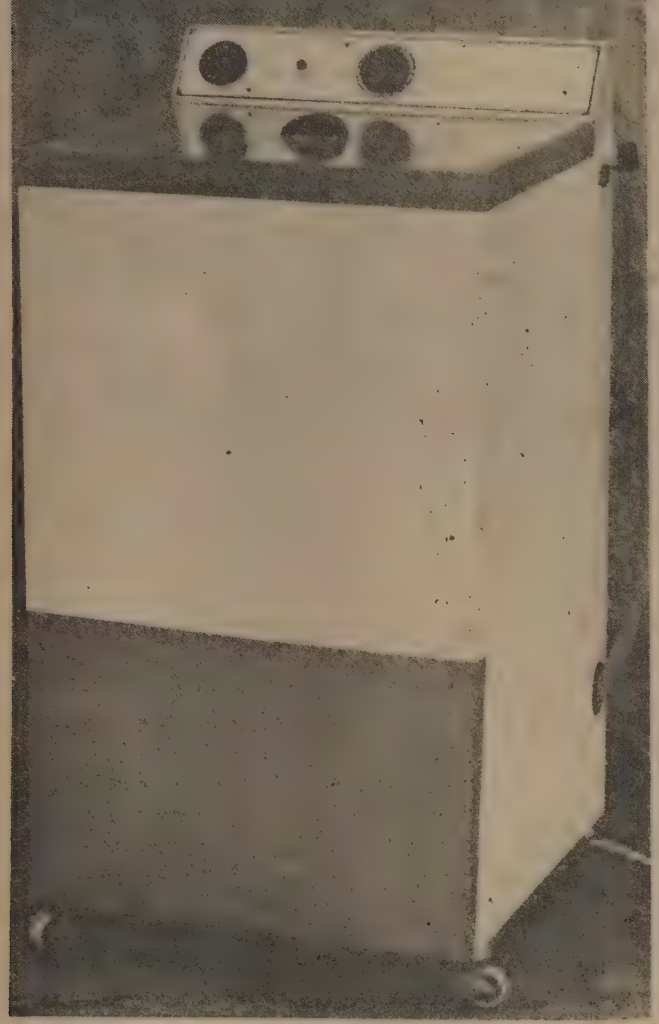
: the manufacturers are reluctant use them for reasons of economy. ew motor will function satisfac-ly, but when it starts giving ble after some time it is difficult the customer to prove that the nufacture was defective. The dealer can always blame the customer for misuse and negligence. In motor-type appliances, compliance with endurance test requirements of the Indian Standards Institution can, therefore, protect the interests of the customer (see box on p. 57).

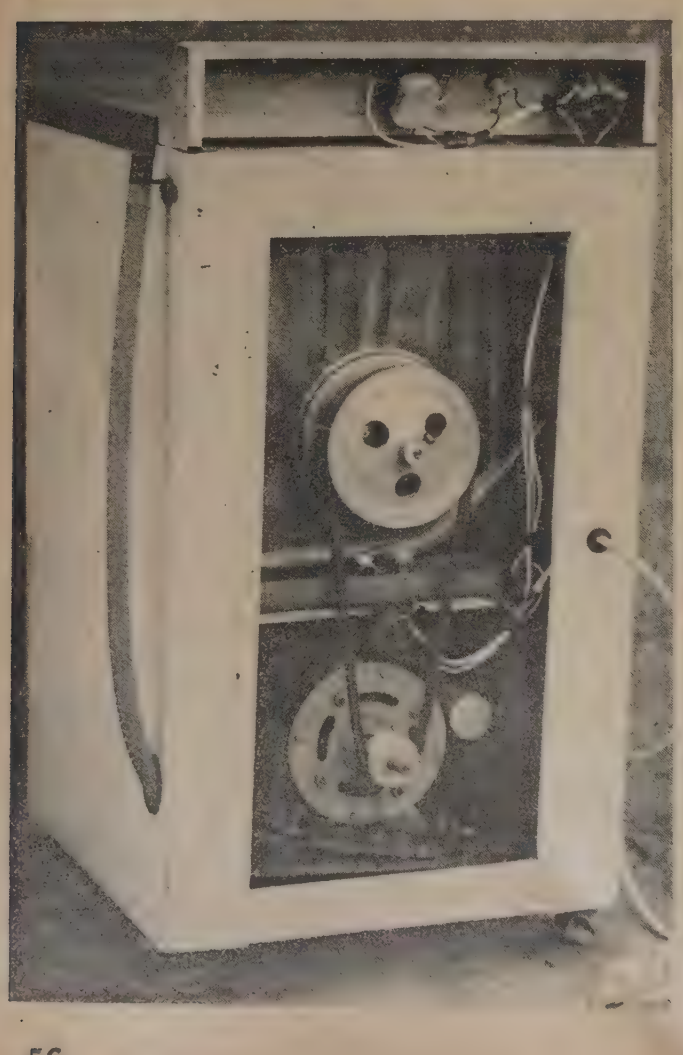
The constructional details of a typical grinder mixer are shown in Fig. 1. The grinder portion is used for pulverising or powdering dry foodstuffs like groundnuts, cereals, coffee seeds, etc. A separate lid is provided for the grinder. When the liquidiser

is to be used, it is fitted on to the grinder portion and the liquidiser blades get coupled to the motor. In another model, the container is common for both the operations, but the blades are changed. The containers are made of either stainless steel or glass or thermosetting plastic. It is necessary that the material used for the container bowl is neutral to food, acids and salts, does not deteriorate with age and is able to withstand temperatures up to 100°C without

Fig. 3. (below) The washing machine

Fig. 4. (bottom) The motor (bottom) and the impeller or the agitator (top) in a washing machine. At the top of the machine is the control panel





change in its physical, mechanical and chemical structures and properties. The cutters and other exposed parts of the machine in contact with food must be made of material which prevents fouling of foodstuffs and resists corrosion and rusting. The mechanical coupling between the motor and the cutter spindle poses some problems (see box on p. 57). To allow for variations in positioning different parts in assembly by the user, small axial and radial displacement must be tolerated by the machine. At the same time, accurate guides have to be provided to ensure proper mounting.

Some precautions are necessary on the part of the user. These are usually given in the instruction sheets supplied with the appliance. The more important points are that the motor should not be started without load, that is, without any foodstuff in the mixer (otherwise the motor attains rather high speeds); there should not be excessive quantity of foodstuffs, either. In the latter case, the motor fails to rotate and draws excessive current. Besides, certain types of foodstuffs like turmeric (*haldi*) and betelnut (*supari*) may be too hard for the cutting blades of the grinders. Fibrous foods like coconut and ginger also pose difficulty in some mixers.

The mixers imported about 15 years ago were generally of the light duty type suitable for European food. They could operate for periods of not more than one minute or so at a stretch. The Indian mixers now available are of the heavy duty type which can operate continuously for 30 minutes.

Washing machines

In India, washing machines have not found a good market. The machines manufactured in our country are of the non-automatic type. This means that successive operations in the complete process of washing require one or more interventions from the operator. The basic unit consists of a washing tub. The clothes are immersed in the tub in a washing solution which is agitated by blades rotated by an electric motor. The main parts of such a washing machine are: (*i*) water container made of stainless steel or aluminium, (*ii*) impeller driven by an electric motor, (*iii*) outer body of mild steel sheets, (*iv*) an ON-OFF switch and indicating pilot lamp, (*v*) wringer consisting of two rubber rollers and a handle, (*vi*) timer (optional), (*vii*) internal water heater (optional), and (*viii*) drain pipe.

If the motor causes the agita rotate in one direction only, a r motion is established in a short Better results are obviously ob with irregular motion. One m to obtain this is to reverse the tion of the agitator blade rotat frequent intervals.

The wringer squeezes out the from the clothes by pressing clothes between two rollers are operated either electricall manually. A centrifugal extra unit, which contains a basket ope by a motor, turns the baske expel moisture centrifugally fro clothes. Another desirable facil to heat the washing solution required temperature. Since diff fabrics require different temperat a temperature-controller is desir Addition of all these facilities m the machine complex.

An important part in a was machine is the rubber gasket at impeller shaft. This prevents w from leaking out at this point. inefficient gasket will let the w seep through and reach the main p of the outer body and the ele motor. This will affect the m insulation and the motor can burnt. The main parts would also subjected to rust and get corro faster.

With a washing machine of above type, the following tempera and time duration for the var types of fabrics are recommended.

Fabrics	Temperature in °C	Time in minutes
Cotton/cotton blended		
White	75 (very hot)	3
Fast colours	55 (hot)	2
Moderate fast colours	40 (warm)	2
Wool/wool blended		
White	40 (warm)	2
Fast colours	35 (warm)	2
Moderate fast colours	30 (lukewarm)	1
Synthetic and mix fabrics		
White	50 (hot)	2
Fast colours	40 (warm)	2
Silk	50 (hot)	1

(*Note:* Increase the time by one minu while washing in cold water.)

It is advantageous to pass clothes through a wringer before ri ing; it helps to recover soap soluti When the machine is not in

STANDARD TESTS

It is well known that an equipment r an appliance which has moving or otating parts gives more trouble than n equipment which has no moving arts. Motor-operated appliances are, nerefore, more prone to trouble. The ear and tear of the motor parts will ventually lead to defects, not obvious t the time of purchase. A customer, nerefore, takes a chance when he uys a product which has not stablished a reputation for quality nd which has not been certified by a ompetent authority after thorough esting. This makes it desirable to carry ut the tests specified in the relevant andards laid down by the Indian tandards Institution.

The endurance test is the most nportant in assessing the long-term erformance of the appliance under st. For motor-operated appliances, ne test prescribes continuous operation r 48 hours at a supply voltage slightly excess of the prescribed maximum ted voltage and for another 48 hours a supply voltage slightly less than ne minimum voltage. At the end of the st, the insulation should not be amaged and contacts and connections ould not work loose as a result of eating, vibrations, etc. There should e no deterioration which can impair fety in normal use.

The routine tests are intended for 00 per cent inspection (see " How to sure quality ", October 1977, p. 49). hey include: (*i*) visual examination, i) protection against electric shock, ii) high voltage, and (*iv*) insulation sistance tests. All these tests are to be rried out by the manufacturer as escribed in the standard on general d safety requirements (IS 302 1973). arthing connection test is also speci- d as a routine test (except in the case shavers). This test measures the sistance between the earth terminal the appliance and each of the cessible metal parts in turn. The sistance should not exceed 0·1 ohm. his would protect the user of the pliance if the earthing in the house properly done. Otherwise the hazard ll still be there (SCIENCE TODAY, ptember 1977). It is, therefore, sential to have the earthing tested, rticularly before going in for a ashing machine. There have been tal accidents with washing machines ue to carelessness in these matters. If the earth terminal in the socket is not connected to a good earth, it can have some high voltage due to the leakage current in the entire installation in the building, including the particular machine. Therefore, it offers no protection at all. Any metallic part of the washing machine can thus have a high voltage on it. Wet hands will make good electrical contact with the metallic surface of the machine. And wet feet and the water spilled around will make good contact with actual earth. Thus the whole voltage will appear across the body resulting in a severe shock.

In addition, the following tests are prescribed as routine tests for the appliances described in this article. For mixers, an operational test with recipes is prescribed. This includes: (*a*) grinding coffee, (*b*) preparation of the idli mix, and (*c*) whisking egg whites. The quantity and quality of foodstuff in each case is specified. In the first two cases, the end product is passed through appropriate sieves to decide the quality. In the case of eggs, the bowl is inverted for five seconds and the material which would be in the form of a stiff froth must remain in the bowl. If the end product passes the tests prescribed, the result is considered satisfactory.

In the case of washing machines, a running test is prescribed in which the machine is put on without load and the various controls are checked for proper operation.

The acceptance tests which are meant for inspecting on a sampling basis include a few more tests in addition to the routine tests. The following tests are prescribed for all the appliances: (*i*) moisture resistance, (*ii*) leakage current, (*iii*) input, and (*iv*) temperature rise. The moisture resistance test is to find out whether the appliance is proof against humid conditions which may occur in normal use. The appliance is kept in a humidity chamber which contains air at approximately 27°C and more than 95 per cent humidity for 48 hours. After the treatment, the appliance should not show any damage. Besides these tests, performance test for washing machines and temperature withstand test for mixers are included in acceptance tests.

The performance test for washing machines meticulously gives details about the quantity of clothes to be used, the composition of soiling and how it is to be done. A mathematical formula is given for the evaluation of soil removal but the august body has not specified what the final values should be. The standard published in 1971 noted that these were " under consideration " (but the amendment issued four years later was still silent on this point). The subsequent clause prescribes in solemn words: " The fabric which emanates after the treatment shall be as clean as it was prior to its being moistened and dirty. This shall be judged visually ". The subjective judgement at the end of the elaborate test makes it of doubtful utility.

In the temperature rise test for mixers, boiling water is poured into the bowl rapidly to fill it to capacity. The bowl is emptied and brought back to room temperature. After repeating this five times, the bowl should not show any sign of cracks.

The type tests cover the full range of performance requirements and check the basic design. Naturally, they include various tests which are taken from the standard on general and safety requirements. Two tests deserve special mention. They are the spillage test and the starting test. The spillage test is prescribed for appliances subject to spillage of liquid in normal use to ensure that it does not affect their electrical insulation. For this test, a specified quantity of water is deliberately poured slowly in the bowl already filled completely with water. The insulation is checked after this spillage.

The starting test for motor appliances prescribes starting the appliance 10 times under the most unfavourable load conditions in normal use and at a voltage equal to 0·85 time the rated voltage. In all cases, the appliance should function safely.

The mixer and the washing machine are costly appliances. The tests described above will assure the customer about the quality of the appliance. Hence compliance with ISI standards should be enforced more rapidly in the case of these appliances. Such a step will be in the interest of both the consumer and the manufacturer.

P.J.J.
S.T.P.

autions should be taken to dry all ssible parts, particularly the area nd the rubber rim at the top of machine. The only maintenance lubricate the impeller shaft and motor at times with a proper icating oil and to adjust the 'V' when it is loose.

western countries, fully automatic ning machines are manufactured built-in water heaters and spin-dryers. For thorough cleaning, the impeller rotation is reversed after eight to ten rotations. The dirty soap water is removed after some time and fresh water is allowed in the container. Finally, the clothes are put in a spin-dryer from which they come out practically dry and ready to iron. All these operations are fully automatic. Once the temperature and time durations are adjusted and a starting push-button is pressed, the machine stops automatically after the washing and drying process is completed.

Hair dryers

Hair dryers use a small fan to blow air. If one needs hot air, a heater element is switched on by a separate switch. The air gets heated as it flows over the heater

element (Figs. 5 and 6). A universal motor is used to drive the fan; it consumes about 100 watts. The heating element consumes about 200 watts. The hair dryer is a hand-operated appliance and may be held by the user in various positions. The motor, therefore, should be mechanically stable. As mentioned earlier, motor-driven appliances need to be tested over a period of time to check their reliability. Since the manufacturers are reluctant to subject their appliances to rigorous tests by an independent authority, customers have doubts about the long-term reliability of the appliances. It is, therefore, both in the interest of manufacturers as well as customers if the manufacturers carry out all the prescribed tests satisfactorily.

Shavers of indigenous make are not available in the market. It is understood that a shaver made indigenously was introduced in the market some time ago. But it was found to be unsatisfactory and had to be withdrawn from the market after refunding money to some customers.

Two of the features, "For Young Readers" and "Let's Get to Know Our Trees" have been held back this month owing to lack of space.

Fig. 5 (above) The main parts of a hair dryer, the fan and the heating element. The heater is switched on by a separate switch. The air gets heated as it passes over the heating element

Fig. 6 (right) Hair dryer

AWARDS & APPOINTMENTS

ICMR Awards

The Indian Council of Medical Research has selected 16 scientists for its 1977 awards in biomedical research.

Dr. R. Viswanathan, emeritus scientist at the V. P. Chest Institute, Delhi, and Dr. R. N. Chowdhuri, former Director of the School of Tropical Medicine, Calcutta, jointly receive the Dr. Kamala Menon award in internal medicine — Dr. Viswanathan for the study of chest diseases, and Dr. Chaudhuri for tropical diseases.

Dr. S. S. Jolly, Professor of Medicine, Patiala Medical College, has won the Basanti Devi Amir Chand prize for his work in endemic fluorosis. Dr. P. K. Devi, Professor of Obstetrics and Gynaecology, Post-graduate Institute of Medical Education and Research, Chandigarh, has been awarded the Dr. P. N. Raju prize for studies in maternal health.

Other award-winners are: Dr. M. I. D. Sharma, emeritus scientist, National Institute of Communicable Diseases, Delhi — Dr. Y. S. Narayana Rao oration award for work in the control of communicable diseases, particularly the eradication of smallpox; Dr. Kamala Krishnaswamy, Assistant Director, National Institute of Nutrition (NIN), Hyderabad — Dr. V. N. Patwardhan prize for work in nutrition; Dr. K. K. Datey, Director of the Department of Cardiology, Medical Research Centre, Bombay — Kalawati Jagmohan Das memorial award for work in cardiovascular diseases; Dr. S. J. Guleria, Professor of Medicine, All-India Institute of Medical Sciences (AIIMS), New Delhi — M. N. Sen oration award for research in respiratory diseases; Dr. S. Padmavati, former Director of the Maulana Azad Medical College, New Delhi — Kshanika oration award for work in cardiovascular diseases; Dr. B. D. Barua, Professor of Pathology and Bacteriology, Assam Medical College — Sandoz award for studies in the epidemiology of oral cancer; Dr. P. K. Ray, former Director of the Chittaranjan National Cancer search Centre, Calcutta — Raja Ravi Singh award in the immunology of ca

Four young scientists (below 40) been awarded the Shakuntala Amir C prizes. They are: Dr. S. N. A. Lecturer in Medicine in the Maulana Medical College, New Delhi, Dr. Sat Singh Hanjan, Department of Biochem AIIMS, New Delhi, Dr. S. K. Bharg Assistant Professor of Paediatrics in Safdarjung Hospital, New Delhi, Dr. Ramesh Bhat, NIN, Hyderabad.

BRAIN TEASERS

LOST IN TRANSIT: Mr. Shambhu wrote and published an interesting book. He despatched some copies to a wholesaler in another town. All were lost in transit. Then he sent as many bundles of copies as the number of copies he had sent earlier, each bundle containing the same number of copies as in the first consignment. These were also lost. He then sent some copies through as many persons as there were copies in the second consignment, each person being given as many copies as the number of pers Now, the copies lost in the third cons ment were equal in number to the se consignment copies. The remainder delivered to the wholesaler, twelve reta approached whom and agreed to tak these copies, provided each of them go same number of copies. Did the reta get their copies?

V. A. SHE

(Solution next month)

Solution to last month's Brain Teaser

Carom with a difference:

Since each strike fetches either of them one point, there were 17 strikes in all, of which the first player made nine and the second, eight. Let the first one have X unsuccessful strikes; hence, the second will have had 7 — X unsuccessful strikes. Further, the first player had 9 — X successful strikes so that he got (7 — X) + (9 — X) ie, 16 — 2X points.

Now 16 — 2X = 9 or 8

Since X is an integer,

16 — 2X = 8, and X = 4

Hence, the first striker got eigh points, and the second won the game

...e weather weapon ...ome facts, some fiction?

... WEATHER WEAPON by N. ...nagiri, National Book Trust of ...a, New Delhi, 1977, pp. 190, ...10

...r. N. Seshagiri has written a very readable book. His capacity to present scientific concepts ...opular and picturesque language ...are among Indian scientists. His ...abilities as a scientist and his flair popular scientific writing could ...e been used to present a more ...nced picture of the subject.

...n the preface, Dr. Seshagiri says ... the book was written solely for ...ussing scientific issues, though he ...ects the reader to suffer " a mild ...l down the spine " by the time he ...es to p. 127. The book should be ...ged by the first criterion.

...he book doesn't give a definite ...entation of the present state of ...ther modification. Unfortunately, author believes that the opinion ...he world community of meteoro...sts that weather modification is largely at the research stage is a ...nsciously hoisted canard' to ...ert attention from developments significant strategic importance. ... World Meteorological Organisa..., in a policy statement, had cau...ed that weather modification ...perations should be undertaken .... on the understanding that desired end results may not ...ays be achieved". The table at end of Chapter III on " Types of ...ironmental modification and their ...ssment as weapons " taken from document submitted by Canada ...the Geneva Disarmament Confer...e is scientifically realistic in taking ... account foreseeable develop...nts. But Dr. Seshagiri's method of ...sentation is to describe some ...parently successful experiment and extrapolate the results up to a ...el of fantasy to create a chill down spine, which effect he has himself ...mitted.

...The book correctly mentions some ...-systems of the monsoon circula...n of South Asia, to which monsoon ...nfall is related. Some of these ...tures are over adjoining oceans and ...ghbouring countries. The author ...ls them soft spots; by tampering ...th these, the Indian monsoon can dried out. In spite of the study of ... monsoon for a hundred years, meteorologists are unable to explain the wide fluctuations in rainfall as cause-and-effect relationships with precedent conditions. Yet Dr. Seshagiri is bold enough to state that " parameters governing the structure of the monsoon are precisely quantifiable and predictable " to plan an attack on the monsoon. As a consequence of the drought weapon, he even pictures that a " government may crumble or political chaos may ensue " !

In this and other cases of weather weapons, Dr. Seshagiri has failed to appreciate the fundamental problem encountered in assessing the success of weather modification experiments. Given an initial state of the atmosphere, the future state is predictable not uniquely but in a probabilistic manner. These probabilistic limits of predictability of weather phenomena and the order of weather modification possible by various techniques so overlap that success can be defined only at various levels of statistical significance, even after trials over a long period. At present, a military commander, having sent his aircraft on a cloud-seeding mission, has to be content with the belief that any floods caused thereby are probably not due to natural forces!

" The seeding of hurricanes has been followed by reduced maximum wind velocities. Confirmation is required from further experiments which should include an increased number of measurements in pertinent regions of the storm." No more is claimed in the 1975 statement of the World Meteorological Organisation on hurricane modification. The book, on the other hand, informs the readers that hurricanes of 1961, 1963, 1969 and 1971 have been steered by seeding. Neither the article of R. C. Gentry, the then Director of National Hurricane Research Laboratory in the book *Weather and Climate Modification* (Hess 1973), nor the " Editorial Overview " (1976) of the American Meteorological Society on " Weather Modification ", mentions any steering of hurricanes by seeding. Dr. Seshagiri's conjecture on p. 62 " that if a number of cyclones are suppressed in the same area and often, the energy conservation factors may cause the creation of super giant cyclones " is pure fiction. He also mentions on p. 102 " a study, by the author, of simulating on the CDC-3600 computer of TIFR a typical operation for controlling the direction of a hurricane so as to hit a specified port or naval installation." This secret work would indeed be a valuable addition to the arsenal of any country!

Interest in weather weapons has been stimulated by the use of seeding to cause flash floods in the Vietnam war. The techniques should have been similar to dynamic seeding of cumuli and cumulonimbus mergers practised by the Joanne Simpson group. Limitations of this method have to be recognised. The considerable US mastery in air in the Vietnam war made it easy to seed clouds in border areas and in the interior of enemy territory. During the monsoon sway, clouds suitable for dynamic seeding might be common, but tampering would not be easy and effective except with air superiority. This seems to be about all there is about weather weapons to reckon with to date. Research, no doubt, is in progress at an increasing tempo by the two Super Powers to exploit other possibilities, but there has been no breakthrough like the silver iodide seeding agent which opened up the vista of regulating the formation of ice crystals.

The author creates a scare of weather modification experiments and operations. Such a scare may beset national programmes with several problems.

Y. P. RAO

[Dr. Rao is Director-General of Observatories, India Meteorological Department, New Delhi.]

MNEMONICS

(Contd. from p. 44)

not be very effective in learning textbook material. The student's learning does not merely involve verbatim recall. The material that needs to be stored in his mind must be 'understood' rather than 'memorised'. Even where factual details need to be memorised, the requirement is not so much a faithful reproduction in an isolated performance as in the context of a generalised problem-solving situation. To quote Hunter again: " Practice in memorising does not of itself improve ability to learn; even ability to learn the kind of material on which practice was expended. But practice can be effective if it is taken as an opportunity to explore, discover, and modify the activeness of learning . . . it can often lead to the development of more effective learning techniques ".

PRADIP PAUL

Entropy and the source of biological order

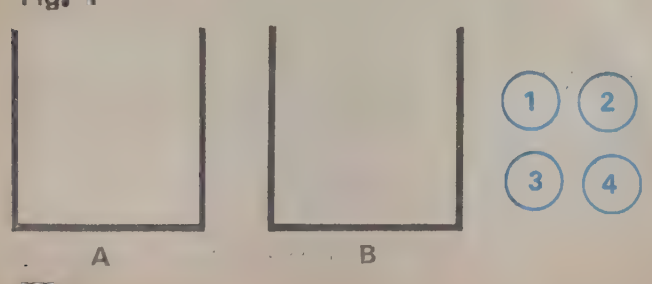
Let us begin with the question: "What is order?" Everybody is familiar with this as a qualitative notion. A rush hour crowd milling around on a railway platform seems 'disordered' in contrast to a group of school children neatly arrayed for a P.T. display. A newly-built skyscraper is an ordered conglomeration of concrete blocks and steel rods; if it collapses, what remains seems less orderly to the intelligent layman. In fact, any society itself is an organised complex of production, circulation and distribution, to say the least. And corresponding to its degree of development, there is a definite correlation and interconnection between its various parts. Each part—be it a person, a production unit or a component of a machine — is placed in definite and precise relation to the remaining system.

Now the maintenance and reproduction of these social systems of organisation of factories, households, economies, etc require the constant efforts of intelligent agents — human beings (however shortsighted and anarchic these efforts may be when evaluated in a historical perspective), and hence it is not difficult to see where the dictum arises that "*any* process of organisation requires the intervention of a conscious, intelligent agent". But is this true?

Before we examine the validity of the above notion, let us sharpen our tools by *quantifying* the concepts of order and disorder, at least in simple cases. What we can do is to quantify the closely-related concepts of "information" and "lack of information". A measure of the latter is known as 'entropy'.

Consider two containers labelled A and B, and four balls, numbered 1, 2, 3 and 4 (Fig. 1). Let us say we have *complete information* about this system when we have specified exactly in which container each ball is situated. And let us agree to call each such 'exact' specification a 'detailed state' of the system.

Fig. 1



Consider now the three following specifications of the system (Fig. 2).

(*a*) Container A has four balls in it.

(*b*) One of the containers has four balls in it.

(*c*) There are two balls in each container.

Fig. 2a

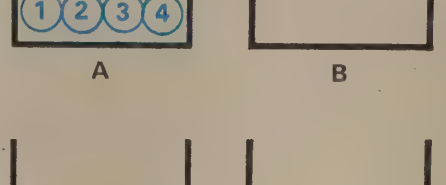


Fig. 2b

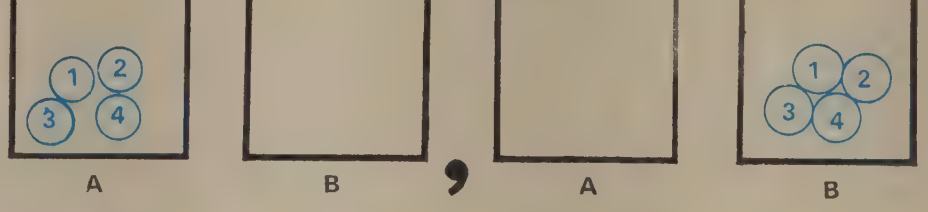
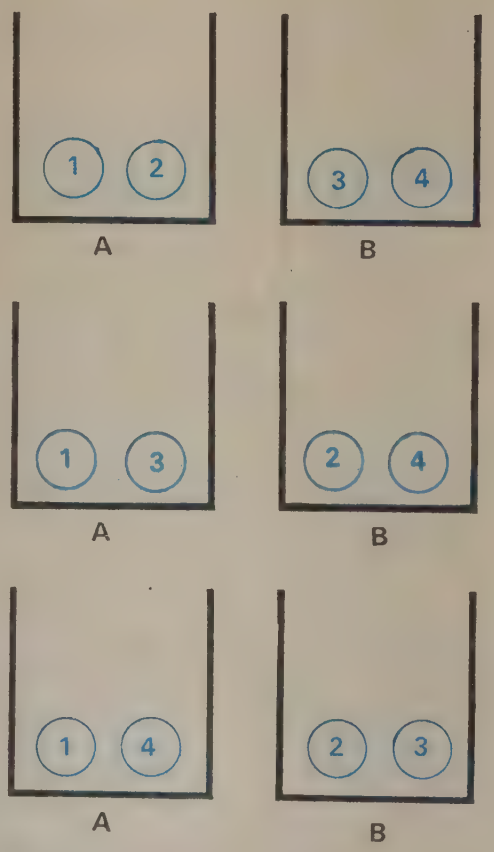


Fig. 2c



It is easy to see that the first specification gives us complete information about the system. However, two 'detailed states' correspond to the second (Fig. 2b) and six t third (Fig. 2c). Both contain but less than complete, inform and the third specification co the least information. Thus, in ral, there will be 'w' detailed corresponding to any specifica where 'w' is some positive integ

In entropy terms, the prece paragraph can be summarised br The three specifications corres to entropies zero, k log 2, and k l respectively. The entropy of a s fication is thus defined as the rithm of the number of det states corresponding to that speci tion, multiplied by a constan (whose significance we do not into here):

S = k log w, where S = entr and w = number of detailed st

. . .

Thus, minimum information responds to maximum entropy. W we have exactly specified a systen is in exactly one 'detailed state' its entropy is zero.

From such simple origins a su and far-reaching theory has b built with ramifications in just ab every field of science, from automo engine design through mathema to neuropsychology.

Any measurement on a phys system, usually gives us some, but than complete, information. For ample, let us take air in a room our system and let us measure volume, pressure and temperatu This tells us something about numerous air molecules — for ample their average energy. But are far from having specified position and velocity of each molec which alone would constitute a co plete specification of the system. Th our specification has non-zero entro which we could quantify by equati (1) if we could define and evalua 'w' in this case. Indeed this can done, but we need not go into th technical details here. In any mac scopic process, say a chemical rea tion like the burning of hydrogen oxygen, we have only partial formation about the reactants — certainly do not know the exa position and velocity of every ato molecule and photon participati in the reaction. We can speak of t entropies of the initial inputs and th of the final products and compare t two quantities.

ow that we have defined a ntitative measure of 'lack of mation', we can also obtain a sure of 'information' in the wing manner: suppose we change specification of a system so that ntropy decreases from an initial e $S_{initial}$ to a value S_{final}. We ne the information gained in process as:

$$I = S_{initial} - S_{final} = -\Delta S \quad \ldots(2)$$

he amount of information gained us defined as being equal to the unt of entropy (lack of informa-) lost in the process. A positive of information corresponds to a tive change in entropy. 'Infor-ion', thus, is also termed 'negen-y'.

he laws governing the changes of opy in physical processes are very ple:

. The entropy of an isolated sed) system can never decrease ond law of thermodynamics). any process through which an ated system passes, the entropy of final products is larger than that ts initial inputs.

. An isolated system tends to a e of equilibrium at which its ropy is a maximum for the given ditions (volume, energy, etc). It ows from this law that a system ch is not in equilibrium has less n maximum entropy, and, con-sely, a system which has less than ximum entropy is not in equili-um. Such systems are known as on-equilibrium' systems.

What about 'open' systems — tems that can exchange matter l energy with their surroundings? ch systems *can* undergo a decrease entropy — but only if the sur-ndings undergo an increase of ropy so that the second law of rmodynamics applies to the lar-, closed "system-plus-surround-s" system.

Now let us go back examine the dictum that "any ocess of organisation requires the ervention of a conscious, intelligent nt". In any process of organisa-n, a number of components are ought into a definite and well-fined relation with respect to each ner. Crudely speaking, we may that each component of an or-nised system sits in a 'container' med by the remainder of the sys-n. This process can be seen to qualitatively akin to the "ball-ntainer" specification example, but th many containers and perhaps any different kinds of balls. *Thus, organisation process is intimately con-cted with a 'decrease in entropy' or an ncrease in information'*. It follows that a *closed* system cannot spontaneously increase its organisation.

The human body, in fact, any biological creature, is a highly organised system. From the moment that the fertilised ovum begins to divide and multiply, and throughout childhood growth, till the time of attainment of maturity and adulthood, the degree of organisation increases progressively. On the other hand, during the process of living, during metabolism, there occur wear and tear — tissues break down, entropy increases . . . yet these tissues are replaced, and a reconstructive process also takes place which reduces the entropy and re-establishes the organisation of the system. What is 'responsible' for the increase in organisation, for the reduction in entropy, in the processes of growth and reconstruction? Do the above constructive and reconstructive processes in the human body, and other living creatures, violate the second law of thermodynamics? Is it necessary for some intelligent agent to intervene, for a miracle to occur, in order that life may exist and reproduce?

Since miracles and superstitions often conceal themselves in pockets of ignorance, it would seem to be an important cultural task to turn out these pockets, wherever possible, and to try to identify the source of biological order.

The first point we must take note of is that a biological system, say, the human body, is not an isolated system, but is very much an *interacting open system*. It receives sensory stimuli, eats food, drinks water, breathes air, exhales carbon dioxide, excretes feces, urine, etc. Food, at a more structural level, consists of complex molecules like carbohydrates (for example, glucose), proteins, lipids, etc. Thus, the human body regularly ingests complex molecules of the categories mentioned above.

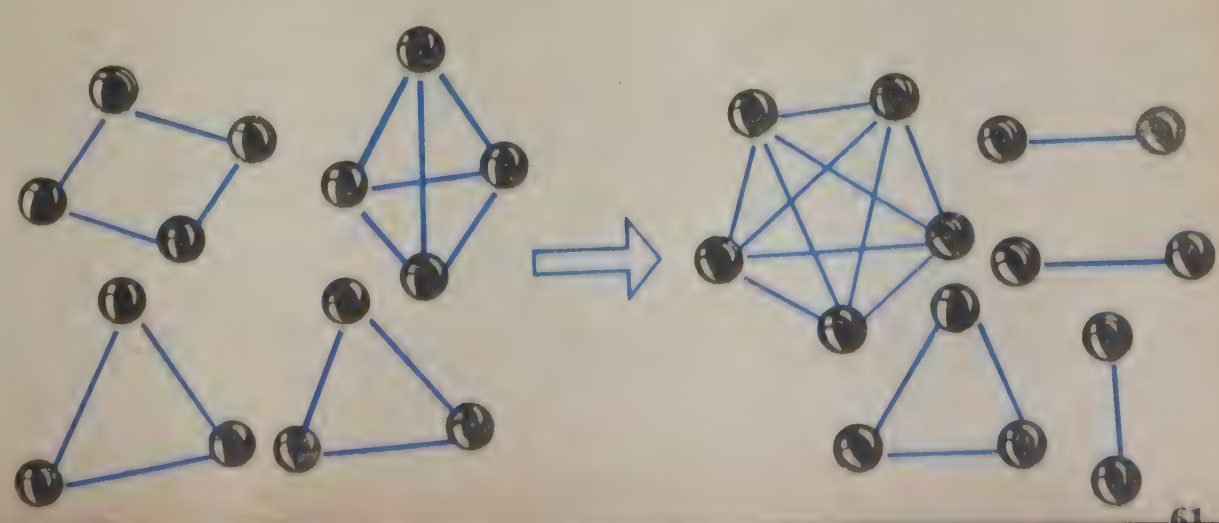
Now the biological life processes consist of two basic types — catabolism and anabolism. In the first, the complex molecules like glucose, amino-acids and fatty acids are 'burnt' in oxygen and broken down into simpler molecules like CO_2, water, nitrogenous wastes, which are then excreted in various ways. The entropy of the by-product molecules is much larger than the entropy of the initial molecules. In information terms, there is an outflow of 'information' during the process of catabolism, which supplies the anabolic processes which are characterised by an increase in order. Thus, rephrasing, we may say that biological organisations undergo two kinds of processes — one in which entropy increases (catabolism), another in which entropy decreases (anabolism). The various *biosynthetic* processes like formation of polysaccharides, proteins, DNA, RNA, and the 'higher' organisation processes mentioned earlier like reproduction of cells, are examples of the latter.

In a certain sense, even the process of thinking might be considered as a "higher" anabolic process. "Understanding" or, "coming up with an idea", consists of organising a set of disparate facts or data elements into a more coherent structure. Does entropy play a role here, too? Since neurophysiological, *material* processes underlie all mental functioning, the organisation of disconnected ideas into coherent understanding must correspond to a material organisation process in the neural network of the brain matter. We can certainly speak of the entropies of this *neural material* before and after the achievement of 'understanding'. (To the best of my knowledge, however, we are far from being able to *measure* these entropies in any thinking human.)

Consciousness and intelligence are also biological organisation processes, and the corresponding reduction of entropy could not take place without a "flow of negentropy" from an external source. In this case the external source is most likely the various catabolic processes in the body. In retrospect, we need to *invert* our original dictum to obtain a correct formulation: it is not necessary that, underlying biological organisation, there should be an intelligent 'miraculous' agent; rather, "consciousness and intelligence require a process

(*Contd. on page 63*)

Fig. 3



Why do waves break?

The breaking of waves on the seashore is a fascinating sight to watch. But, why do waves break? What happens during breaking itself? Even after a hundred years of theoretical and experimental study, there are large gaps in our knowledge about this very commonplace phenomenon. Some understanding, though, has been reached on the conditions just before and after breaking.

What makes a study of breaking waves so important? One could cite a variety of reasons. Such waves enhance the air-sea exchange of gases and particulate matter, transfer horizontal momentum to surface currents, provide a source of turbulent energy to raise the upper layers of the ocean and can, at times, cause largescale destruction to man-made structures. It is well-known that large areas of our seashores are being eroded by waves.

An ocean wave is characterised by its wavelength (distance from crest to crest), water depth and wave height (Fig. 1). The inertia of the fluid, the pressure gradient and the acceleration due to gravity, are the three dominant forces acting on ocean waves. When the depth is greater than half the wavelength, the wave is in deep water, since it does not feel the effects of the bottom portion. Smaller values correspond to shallow waves. The other important ratios besides (d/λ) are wave steepness (H/λ) and height-to-depth ratio (H/d). When these quantities are less than one, the wave can be treated mathematically as a small amplitude wave. The profile of such a wave is symmetric about the vertical line passing through its crest.

Fig. 1 In a small-amplitude sinusoidal wave in deep water, the fluid particles have circular orbits (indicated by arrowheads). The orbital radii decrease rapidly with depth

The approach so far has been to start with small amplitude waves and to consider progressively higher symmetric waves which propagate without change of shape in water of constant depth. For a fixed wavelength and depth, there exists a wave of maximum height which is just about to break. Analytically, one corrects the small amplitude approximation for the effects of increased wave height in successive order until sufficient accuracy is obtained. Each successive correction may be thought of as one member in an ordered series of corrections called a perturbation series. It is difficult to do algebraically higher-order corrections and, indeed, the tenth-order deep water correction was not obtained until 1914 and the fifth-order general depth one was found in 1955. Computers have, recently, enabled the series to be expanded to very high order and summed efficiently, thus providing accurate answers up to very near the highest wave.

The computations have shown that for low — but finite — amplitude waves, the speed of wave propagation (the phase speed) increases with the wave height. The wave profile no longer remains symmetric about its mean level, but instead the crests become higher and sharper and the troughs flatter. The phase speed, momentum and energy of the waves were found to increase with wave height, reach a maximum and then decrease as the highest wave was approached. An important observation was that the highest wave is not the most energetic as had always been assumed.

In general, at a wave crest the fluid particles move forward at a speed less than the phase speed and as higher waves are considered, the particle velocity approaches the phase speed.

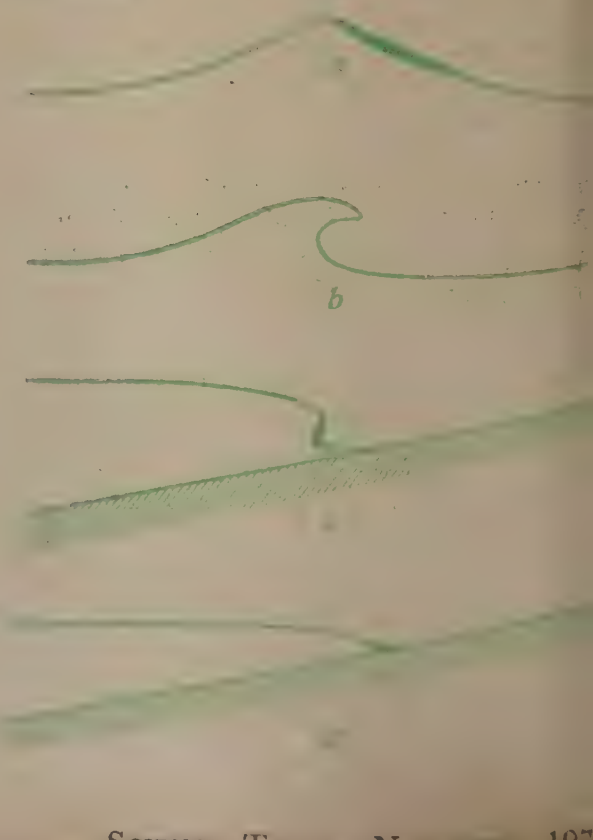
Fig. 2

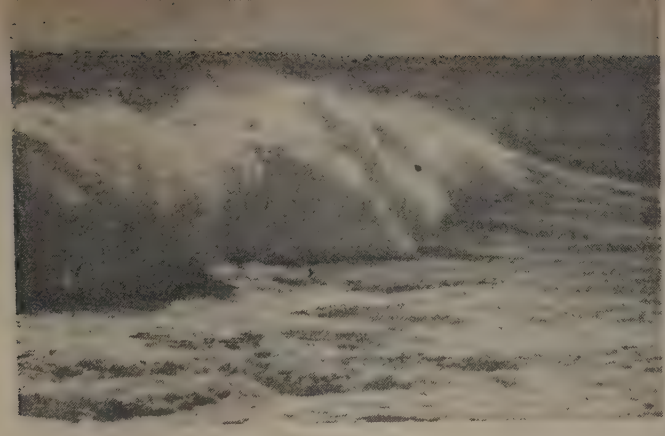
In the limiting case, the two veloc become equal. A further increase wave height will cause the fluid pa cles to overtake the wave itself breaking will ensue. In the refere frame moving with the wave, water comes to rest at the crest attains a sharp point with an incli angle of 120° (Fig. 2). Roughly spe ing, a wave will tend to break eit when the wave height reaches abou seventh of the wavelength or wh the water depth shoals to about times the wave height.

Several laboratory experime have been carried out to test t validity of the steady wave theori Indeed, it is difficult to produce ve high waves which remain steady a do not break in such experimen Though some agreement betwe theory and experiment has be reached, there are more discrepanci since small-scale controlled laborato experiments cannot be correctly extr polated to actual oceanic conditio

Laboratory experiments with shoa ing waves, however, indicate th breakers can be classified into fo main types — spilling, plunging, co lapsing and surging (Fig. 3). A spillin breaker occurs when a steep wav approaches a gradually shoaling beac and has a turbulent plume of froth water running down its forward fac

Fig. 3 There are four main breaker type (*a*) spilling, (*b*) plunging, (*c*) collapsing, a (*d*) surging





4 Above: Plunging wave in shallow . Right: (top) Collapsing breaker; and om) surging wave

a plunging breaker the wave pens and overturns, ejecting a jet vater from near its crest which tually strikes the surface below. a collapsing breaker, the wave turns not at its crest, but lower n the forward face, and a region hite water forms possibly due to close proximity of the bottom. The ing breaker moves up a steep ch as the forward tip of a low e. It resembles a standing wave ned by total reflection from a ical wall, but a small amount of bulence may be present at the ch face. Spilling and plunging akers can also occur in deep water. lapsing and surging breakers do occur in deep water.

xperiments with breaking waves shallow water have concentrated how the ratio of wave height to er depth at the break point $_b/d_b$) and the ratio of breaking ve height to initial wave height $_b/H_\infty$) vary with the initial wave pness, and beach slope. But not a at deal of confidence can be placed on some of the empirical relationships derived on the basis of some scattered experimental data. What is more, no analytical theories adequately describe the time-dependent process of wave breaking.

After a wave has broken, it advances shoreward as a bore. Recent numerical investigations have followed the water up the beach until its forward tip gets very thin and then to follow its subsequent rush seaward (backwash) which itself develops into a bore. The backwash stage may be of significance for sediment transport studies.

The above is a summary of an excellent review on "Breaking waves" by E. D. Cokelet of the Institute of Oceanographic Sciences, Wormley, Surrey, UK, and published in *Nature* (**267,** 769, 30 June 1977). Next time, you watch the fury of a breaking wave, remember that much remains to be understood of this most commonplace phenomenon.

K.A.N.

TROPY *(Contd. from p. 61)*

biological organisation". As for logical organisation itself, its needs simple: it can survive on a diet of egentropy' from an appropriate rce.

Of course, the entropy of the final oducts of the anabolic and catabolic ocesses together must be greater an the entropy of the initial inputs the second law of thermodynamics not violated. We may summarise saying that the living organism es in highly organised food struc- es, converts a small part of these o even more highly organised sue structures, together with the lk of disorganised molecular by-products, which it discharges (shown schematically in Fig. 3, p. 61). The source of biological order in the higher organisms is, thus, primarily the food that it "eats", or ingests.

Having lost his accommodation within the biological organism, our "intelligent agent" is compelled to climb into his only possible refuge — the food molecule. Granted that the source of biological order in humans and other higher organisms is the food molecule, but how did the food molecules acquire their higher organisation (their negentropy, if you wish)? We will examine this question in a subsequent discussion.

VIVEK MONTEIRO

IN LIGHTER MOMENTS

That cowpox provides immunity from smallpox was very well known to village dairymen. Jenner is generally credited with the discovery of the relationship between the two diseases by making the "vaccination" experiment in 1796. But, in reality, the first to perform such an experiment was another Englishman, a Dorset peasant named Benjamin Jesty. He had begun trying out this "immunising" in 1774 on the members of his own family, but he was ignored. And Jenner almost certainly would have missed recognition if he had failed to get support from abroad — the Royal Society was originally not prepared to accept his own evidence.

* * *

The German chemist, Julius Lothar Meyer was more fortunate than most scientists in the matter of priority. In 1882 the Royal Society awarded its Davy Medal to him jointly with the Russian chemist, Mendeleev, for contributing to the formulation and development of the Periodic Law of the elements. Generally regarded as the father of the Periodic Law, Mendeleev's first clear statement was published in 1869, followed by its final version in 1872, while Meyer had drawn up in 1868 (though not published) a classification of elements similar to Mendeleev's 1872 version. Even in 1861 Meyer had published tables of the elements in order of atomic weight in his book *Die Modernam Theorien der Chemie.*

* * *

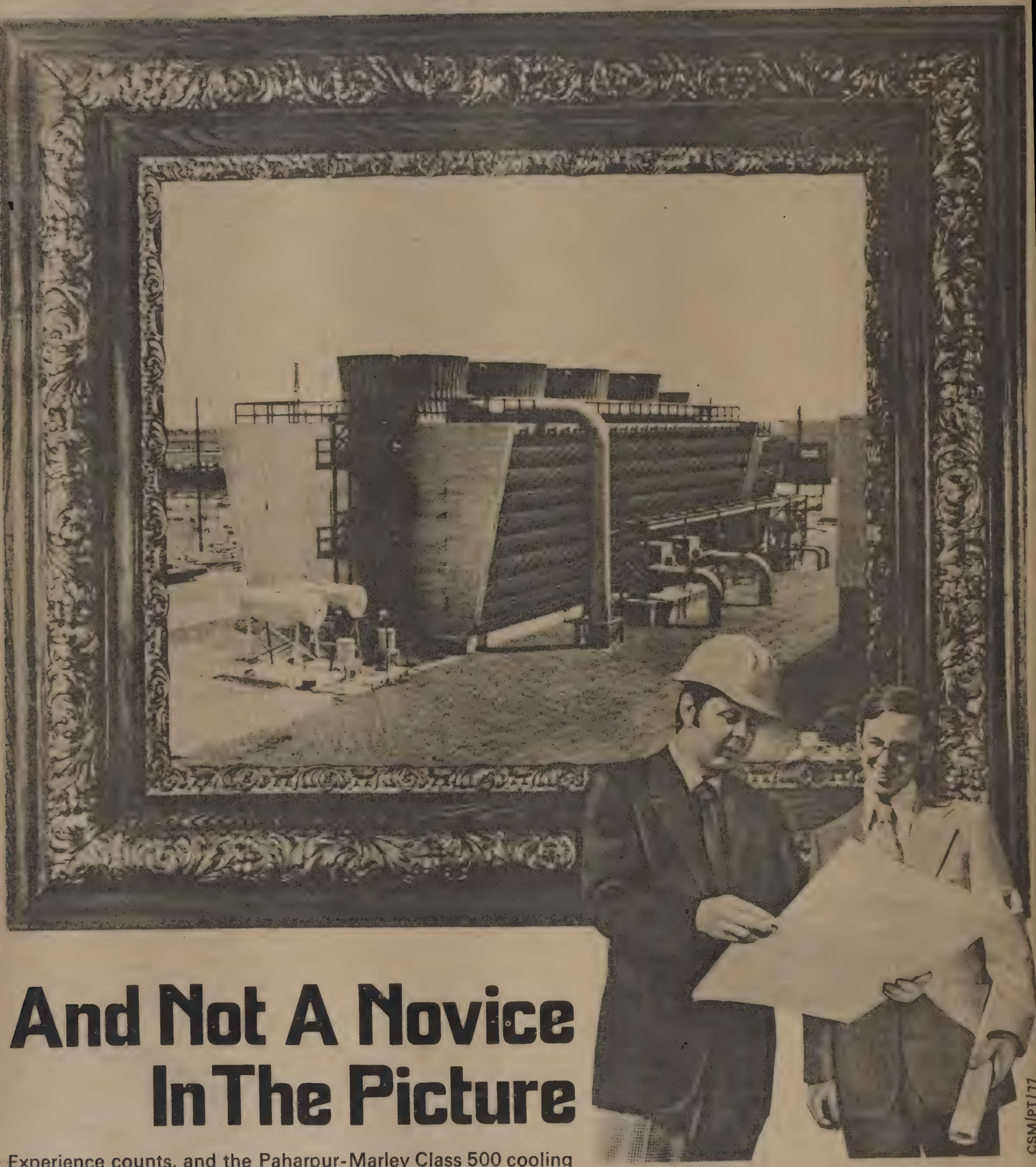
At the historical 1860 annual meeting of the British Association which witnessed the great debate between William Wilberforce and T. H. Huxley over Darwin's *Origin of Species,* when order was restored and the chief actors had retired to their seats, suddenly an old man stood up with a copy of the Bible in his hand and shouted at the top of his voice; "I believe in its unimpeachable authority and deny the claim of the *Origin* that it was a logical statement of fact. . . . How much I regret its publication. . ." He was none else than Admiral Robert FitzRoy, once the captain of *HMS Beagle,* on which the 'creator' of the *Origin* had made his epoch-making voyage.

* * *

The second conference of chemists of Europe held in 1860 broke up like that of 1840 (both were organised by Gerhardt and Laurent) and failed to reach any agreement on any problem. The only commonly shared result of the conference was that each member dispersed with a copy of Cannizzaro's little-known pamphlet, *Sketch of a Course of Chemical Philosophy.* The pamphlet made the most lasting impression on the German chemist Lothar Meyer, who said: "The scales fell from my eyes, doubts vanished and were replaced by a feeling of the most peaceful assurance."

S. N. MUNSHI

34 Frame Sizes



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RINTED CIRCUIT OARDS

rinted circuit boards (PCBs) provide neater, lighter and compact circuit assemblies. By using these ards, the chances of making wiring ors are considerably reduced. At the ne time, they enable the circuit to be nstructed and assembled much faster. ey also provide excellent physical bility of the components as well as ir interconnections.

These printed circuit boards are conucted from copper clad laminates. Inating materials, for example, paper enolic or epoxy are laminated, either one or both sides, with copper foil of ckness from 0·025 mm to 0·25 mm. the two basic insulating materials, digenously manufactured paper phelic is cheaper and more freely available. r almost all normal uses the singleed paper phenolic laminate is used.

On the single-sided printed circuit ards, the uncladded side, that is, where ost of the components are mounted, is lled the component side and the other e which makes the interconnections of circuit is called the printed circuit e. The chemical process given below is providing the required printed circuit ttern on this side by chemically etching unwanted portions of the copper clad.

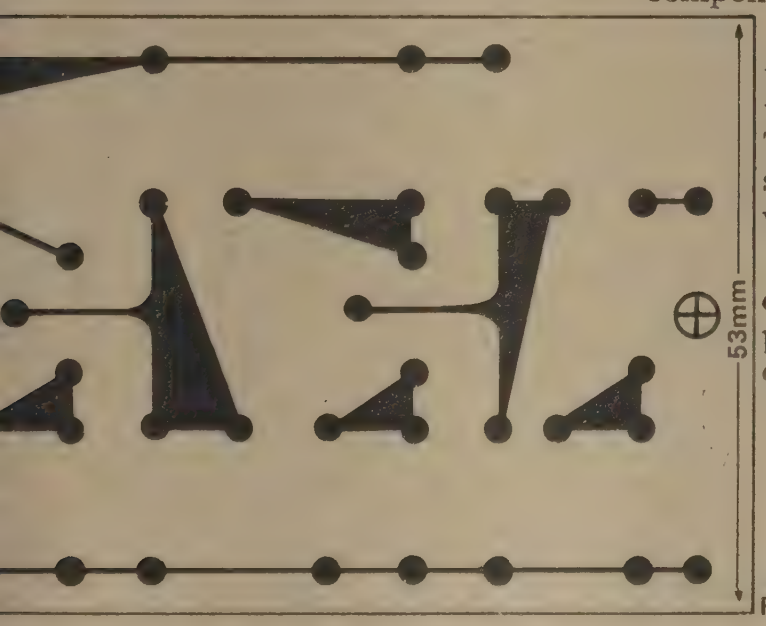
Normally, external controls like itches, potentiometers, lamps, sockets, etc, of an electronic equipment are not mounted on the PCB, because of their placements. The transformers and power relays are kept aside because of their weight. The semiconductors which carry considerable current and thus become hot are normally placed on heat-sinks and not on the PCB.

Construction: Take a graph paper and all the components which are to be mounted on the PCB. Arrange the printed circuit (PC) pattern, by placing the components on the graph paper, as if the pattern were on the component side. Have a separate connection for mounting the components as well as for external leads. Never have two leads in one connection. For each connection, have a dot of at least about 3 mm diameter to avoid the breakage of the foil while drilling the laminate. Keep two interconnections of the pattern at least 2 mm apart. You will have to reduce these limits while designing the PC pattern for integrated circuits (ICs). Try to keep the flow of the circuit on the PC pattern, that is, keep input and output on two opposite sides, the D.C. supply on top and ground at bottom. Try to lay out the pattern in such a way that the interconnections don't cross each other. Arrange the interconnections between the connecting points of components. If unavoidable, you will have to have a 'jumper' wire on the component side. Use the minimum of these jumper wires and make sure that they bridge no component but only the PC pattern.

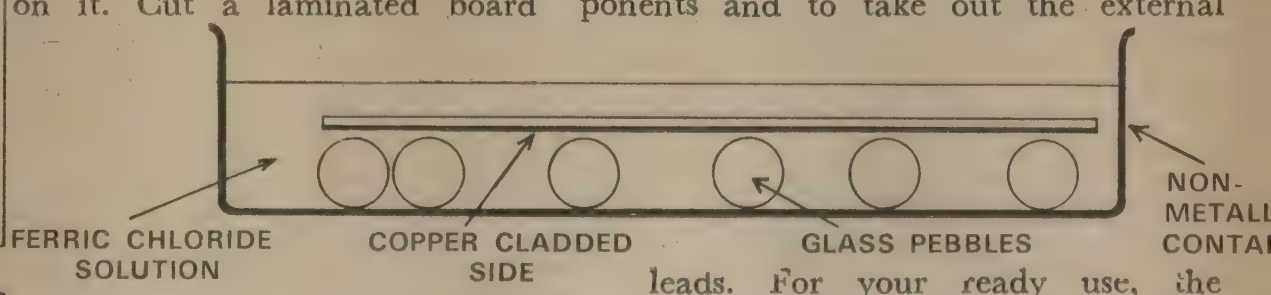
The following procedure is for transferring the pattern drawn on the graph paper to the copper foil. This procedure is suitable for constructing experimental PCBs, where just one or two are required.

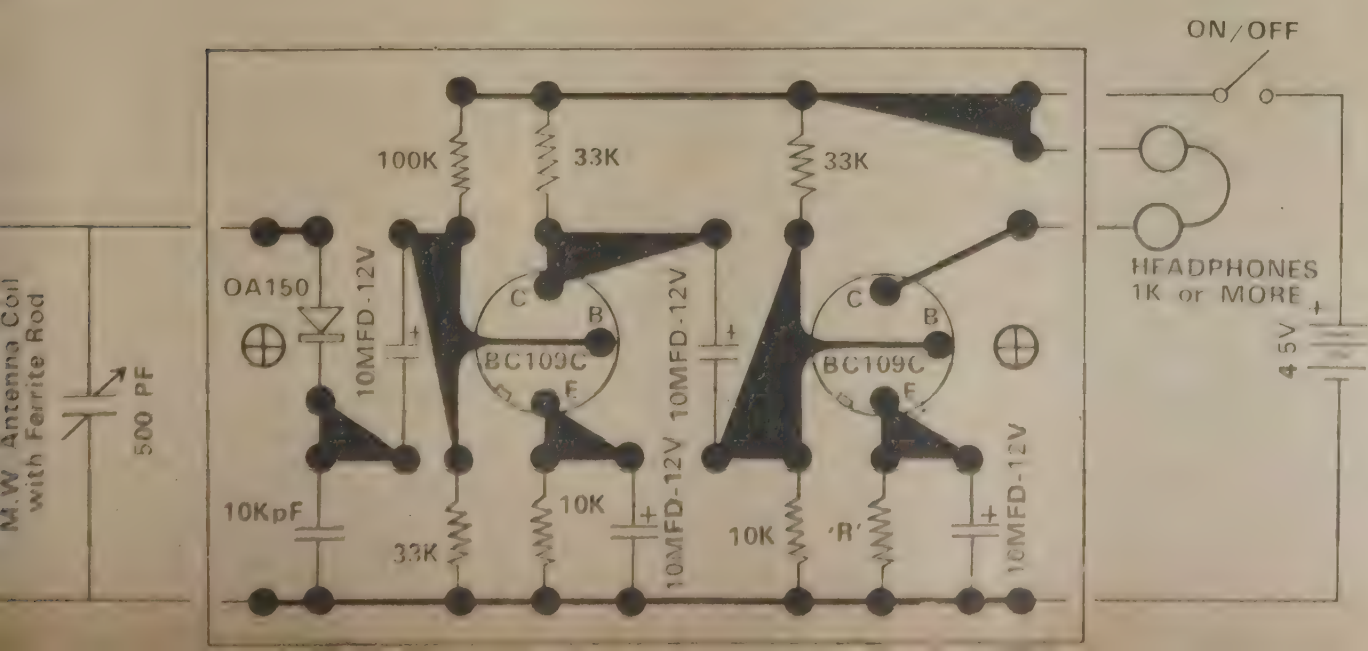
When the pattern is complete on the graph paper, take a tracing paper and trace the PC pattern on it. Cut a laminated board of the required size and wash it thoroughly with soap and water to remove the oil stains and finger-prints. Now, take a fresh carbon paper and keep the carbon side facing the copper side of the laminated board. Keep the tracing paper on the carbon paper in the reversed way. Thus, the component side view of the pattern will become the required PC side view. Now trace upon the tracing paper, from its reversed side, with a hard pencil so that the copper clad will get the required PC pattern from the carbon. Remove the carbon and tracing paper and paint the pattern with India ink or any air-drying enamel paint. Let it dry out for about 24 hours.

Make the etching solution in a tray or dish-like non-metallic container, for example, glass or plastic, of one part ferric chloride in powder form with two parts of water. Stir the solution till the ferric chloride gets completely dissolved. The quantity of the ferric chloride solution required is just enough to immerse the painted laminate. As the ferric chloride dissolves, the solution will become warm due to exothermic reaction. Put a few glass pebbles in the container to keep the board off the container's bottom. Maintain the temperature of the solution at 55 to 60°C by external means. Stir the solution gently, so that the solution will etch out the unwanted copper not covered by paint. The etching process will require 30 to 40 minutes. The etching strength of the solution gets reduced after processing a few boards. When the etching time get doubled, you will have to replace the solution. When the etching is complete, take out the board and wash it thoroughly with clean water and soap. Now, to uncover the painted PC pattern, clean the paint with thinner and soft/medium steel wool. Once again, wash the board with water and let it dry. Drill 1 mm holes, wherever required, to mount the components and to take out the external leads. For your ready use, the complete component side view and PC side pattern of the portable radio published in SCIENCE TODAY, September 1977, is given below. You can use the pattern in the same way, transferring the pattern from the reversed tracing paper.



PRINTED CIRCUIT SIDE VIEW





Warning: Though the ferric chloride etching solution is quite safe to handle, avoid direct contact with it. If you happen to get some on your body, wash the area of contact with clean water. Protect your eyes from the solution.

You will need:

Ferric chloride: 450 gm (cost: about Rs. 5 per kg); glass pebbles, 15 nos.; non-metallic container; copper clad laminate, etc.

ANIL V. BORKAR

Hum-drum Dinners turn Yum-Yum with Amul Cheese!

ıl Cheese ıssaka

prepared mince
tomatoes • 1 large brinjal
potatoes (sliced round
ed)

Cheese Sauce

butter • 2 tbsp flour
milk • Salt • Pepper
ed mustard
sp grated Amul Cheese
l onion

utter. Saute onion till light
. Add flour and fry lightly.
ilk gradually stirring
uously till sauce thickens.
heese and seasoning.
Cheese melts.

repare Moussaka

ase and sides of a well-
d ovenproof dish with fried
es. Roast brinjal and
e skin. Chop roasted flesh.
, peel and chop tomatoes.
matoes and brinjals and
asoning. Put half the
ty of mince on top of
es. Arrange tomato-
mixture over it. Cover with
mince. Pour Cheese Sauce on top. Bake in a moderate oven till Sauce has set. Serve hot or cold with green salad.

Amul Cheese Panir Masala

500 gm Amul Cheese Chiplets, cubed • 1 large onion
2 flakes garlic • Ginger, 5 cm piece
Tomato puree of 5 tomatoes
Butter for frying ginger
1 tsp coriander seeds
1 tbsp cummin seeds
1 tbsp cornflour • 1 cup milk
Fat for masala

Grate onion, garlic, ginger and fry in fat till brown. Add coriander and freshly ground cummin paste. Fry again for two minutes. Now add tomato puree to masala. When masala is well blended and leaves grease, pour cornflour which has been diluted in milk, cook for some time. When boiled add 2 cm pieces of Cheese to masala. Just before serving fry finely-sliced ginger in butter and pour over the dish. For exotic glamour, cover with silver foil!

Amul Cheese Alu-Mosaru

4 potatoes (medium)
2 cups thick curds
50 gm grated Amul Cheese
Salt • Pepper

Peel the skin and boil potatoes well. Mash, add salt and pepper. Mix with grated Cheese. Put this in the curd. Mix well. Serve with puris, chappatis or rice.

Amul Cheese Meal-In-One

4 large slices of toast
4 big slices fried bacon
4 large tomatoes, peeled and sliced thickly
2 tbsp French Dressing
1 cup Cheese Sauce (as for Amul Cheese Moussaka above)
4 eggs

Arrange toast on the baking sheet. Cover each with bacon, tomato and French Dressing. Now poach four eggs. Place an egg on each toast, pour quarter cup thick Cheese Sauce on each of them. Grill, lightly. Serve at once.

Amul Cheese Mornay Cutlets

½ loaf of luncheon meat
2 cups flour • 55 gm butter
½ pint milk
150 gm Amul Cheese Powder
150 gm fresh white breadcrumbs
6 potato crisps, crushed

Make a very thick sauce with butter, flour and milk. Add Cheese Powder and fresh white bread-crumbs. Cut luncheon meat into small pieces and mix gently into sauce. When cold, form the mixture into cutlet-shape and coat in crushed potato crisps. Serve hot by heating under grill.

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Spurred by the success of Bombay High, ONGC is planning to search for oil in a number of other offshore sedimentary basins.

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SUNDAY STANDARD
Vijayawada, Sunday October 17, 1976

Raw Garlic is anti-bacterial

NAINI TAL Oct 29 (Samachar)

Raw garlic possesses anti-bacterial property against a number of micro-organisms including those which are resistant to commonly used anti-biotics. This is revealed in researches conducted at the Pantnagar University. According to the researchfindings, anti-bacterial property of garlic is lost on boiling.

Eve's Weekly
July-17-1976

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Suresh Chandra Chaturvedi

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Regular use of garlic helps the digestive system and removes gas and constipation. It increases the blood, cures chronic cold and cough. Gastric troubles are cured by taking garlic every day.

THE TIMES OF INDIA
BOMBAY DEC 3-1976

Eat Garlic and Cut Cholestrol

NEW DELHI, December 2: A medical study has revealed that garlic is effective in reducing blood cholestrol. An experiment by Dr. R. C. Jain, pathologist at the University of Benghazi in Libya has now shown that garlic reduces the cholestrol level.

He did the experiment on rabbits which he fed with a diet containing large amounts of Cholestrol for 16 weeks. Their aorta (main blood vessel) and liver were deposited with cholestrol but after giving them garlic, he noticed that the fat dissappeared and the blood cholestrol came down. Dr. Jain has reported the results of his experiment in "The Journal of Indian Medical Research" How exactly garlic brings down cholestrol level is, however, not clear, Dr. Jain said-Samachar

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